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THE FLOW OF METALS.

By DAVID TOWNSEND.

In investigating the subject of the punching of metals, and the consequent flow which occurs, no exact law could be determined, covering all cases, owing to the limited number of experiments made, and also to the want of technical knowledge on the subject. M. Tresca, in *La Poinçonnage des Métaux*, published some experiments on the punching of iron, but his results cannot be accepted as complete and accurate, owing to the fact that the means at his disposal were limited; those that were arrived at, were for the action of a large diameter of punch upon small thickness of metal. His experiments were made with a punch of 1·18 inches diameter (30 mm.), on iron plates, the greatest thickness being ·669 inch (18 mm.), and the least ·1968 inch (5 mm.). He announced, as the result of his investigations, the general law that "*when pressure is exerted upon the surface of any material, it is transmitted in the interior of the mass from particle to particle, and tends to produce a flow of metal in the direction in which the resistance is least.*"

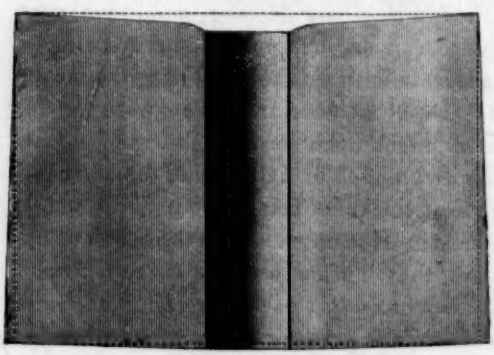
The following experiments were made with nuts, or bars, punched, cold, by Messrs. Hoopes & Townsend, and are intended to show that an actual flow does take place in metals under pressure, which flow is governed by some law not yet enunciated.

The first experiments were made with rectangular blocks of iron, which were planed accurately to the dimensions given in the table below, and then punched, cold, through the centre of the block.

BEFORE PUNCHING.				AFTER PUNCHING.				
Width.		Thick.	Length.	Width.		Thick.	Length.	
				Top.	Bottom.		Top.	Bottom.
No.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1	1·745	1·748	2·51	1·775	1·82	1·748	2·511	2·562
2	1·742	1·748	2·51	1·768	1·814	1·748	2·510	2·552

From the above table, it is seen that, as the punch entered, a flow took place, which was greatest in the width—the direction of least resistance—the length being but slightly increased. By comparing the widths at the top and bottom, we see that the increase has been greatest on the bottom face of the block. From this we should conclude that the flow was greatest at the bottom of the piece; but such is not the case, for the block, resting against the immovable bed of the machine, could not curve down as could the metal at the top, and was, therefore, compelled to spread laterally, producing this increased width.

Fig. 1.



If we examine the punched block, we notice that it has bulged in the width, producing a curved surface, concave towards the axis, greatest at the central line of its width, and decreasing gradually in either direction as it departs from that line.

The length is also increased, but not as noticeably as the width. When the punch first touched the block, the whole upper face was depressed (Fig. 1), the surface converging towards the hole as the lowest point, in the immediate vicinity of which the metal curved sharply downward, like water flowing into an orifice. This depression can be seen in Fig. 1, which is a longitudinal section, the dotted lines being the dimensions of the block before punching, and the black lines, after. We also see that the block has become wedge-shaped, and is slightly convex on the bottom face.

If now we look at Fig. 2, which represents the core punched from the block, we see that it is only $1\frac{1}{16}$ inches in depth, while the hole from which it came was $1\frac{3}{4}$ inches thick. At first sight, it would seem that all the metal from the hole had been squeezed into the core, and, therefore, that its density must be increased directly as this ratio of thicknesses. To prove that such was not the case, a piece of metal was chipped from block No. 1, and its density taken, with the following result:

Fig. 2.

Weight in air,	3·78	gms.
" " water,	3·297	"
Loss,	·483	"

$\therefore \frac{3{\cdot}78}{{\cdot}483} = 7{\cdot}82 =$ density of the block.

The core itself was then treated in a similar manner, giving:

Weight in air,	14·9965	gms.
" " water,	13·07	"
Loss,	1·9265	"

$\therefore \frac{14{\cdot}9965}{1{\cdot}9265} = 7{\cdot}78 =$ density of the core.

From this it appears that the density of the block is slightly more than that of the core; but this difference is probably due to the density of the surface being increased by chipping and filing, and also to the preponderance of matter in the block over the core. As the density has not increased, there must have been a flow of metal from the core into the block, the amount of which we will now determine.

Three experiments were made with blocks of the same thickness and diameter of hole, and the volumes of the resulting cores were determined by displacement, on account of their being irregular bodies. All the experiments being made with the water at a constant temperature, no correction is necessary for differences of temperature.

Core from block No. 1:

Weight in air, ...	14·9965 gms.
" " water, ...	13·07 "
Loss, ...	1·9265 "

The weight of the water displaced is therefore 1·9265 gms., and is equal in volume to that of the body producing the displacement. As 1 gramme of water exactly equals 1 cubic centimetre, the displaced water has a volume of 1·9265 cubic centimetres, which is also the volume of the core. Now as 1 cubic centimetre = ·06103 cubic inch, the volume of the core in inches is equal to ·11757295 cubic inch. If, now, we take the measurements given in the table, and calculate the volume for a hole of $\frac{7}{16}$ inch in diameter, we find:

V = ·3773294 cubic inch = volume of hole.
V = ·1175743 " " = volume of core.

·2597551 " " = volume of the metal which has flowed into the block from the core in the process of punching; and corresponds to 68·844 per cent.

Core from block No. 2:

Weight in air, ...	14·864 gms.
" " water, ...	12·953 "
Loss, ...	1·911 "

This loss is equal to a volume of ·1166283 cubic inch. The volume of the hole being the same as before, we have:

V = ·3773294 cubic inch.
V = ·1166283 " "

·2607011 " " = volume of metal flowing, which is equal to 69·09 per cent.

The third example was a finished hexagon nut, having the same thickness as before and same diameter of hole.

Core of No. 3:

Weight in air, ...	15·154 gms.
" " water, ...	13·220 "
Loss, ...	1·934 "

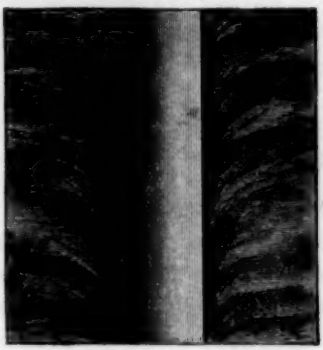
The volume of the core is therefore equal to ·117974 cubic inch, and we get:

$V = ·3773294$ cubic inch.
$V = ·1179740$ " "

·2593554 " " = volume of metal flowing, or 68·73 per cent.

Similar experiments were tried with other thicknesses; but the flow was not so marked, and seemed to decrease directly as the diameter of the hole increased, and as the thickness of the bar decreased.

Fig. 3.



In order to show to the eye, the flow which had thus occurred, several of the large nuts with their cores were planed in half. The resulting rectangular faces being brightly polished and perfectly clean, were then etched with acids of various strengths, when they presented the appearances of Figs. 3 and 4.

Fig. 4.

The curved lines mark the laminæ, or plates, which were piled and rolled together, to make up the bar. It will be noticed that they all curve downward, and that the greatest curvature occurs at the top, remaining nearly constant for some distance, and then decreasing towards the bottom. This shows that the flow must have occurred when the punch first entered the bar, and was continued regularly, until the pressure above parted the under face, and the core was forced out. If we examine at the core, we find that at the top, where the punch first strikes the block, it is concaved upwards, and that the laminæ composing it are forced

in curved layers before the punch, until the resistance of the lowest part of the metal was overcome, when we find that the curves get more and more flat, until at the bottom face there is a slight concavity, due to the flow which took place through the opening in the die.

In the case represented in Figs. 5 and 6, the hole was punched *with* the grain, instead of *across* it, the result being that the superposed laminæ, instead of being curved downward,

Fig. 5.

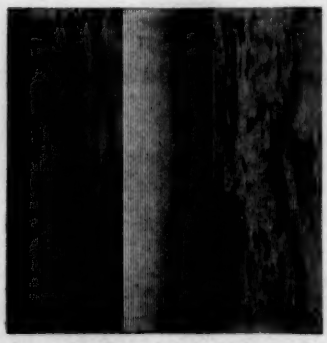


Fig. 6.

were wrinkled or warped, from the flow and the consequent pressure which took place, acting against their sides or faces.

Acting on suggestions obtained from the above results, several experiments were tried by partially punching bars of the same thickness with punches that had the same diameter, but which varied in length according to the depth of the hole to be punched. The bars were uniformly $1\frac{3}{16}$ inches thick, and the punch $\frac{7}{16}$ inch in diameter; the following were the results obtained:

1. The first bar was punched to a depth of exactly $\frac{1}{8}$ of an inch; the resulting piece was then planed in half, polished, and etched with acid, when its surface had the appearance of Fig. 7. Here we see that, although the punch has gone half way through the bar, it has hardly marked the under surface. If we observe the lower portion of Fig. 7, we see that some of the layers have not yet been bent out of shape, and, therefore, that the marking of the under surface could not have been due to the flow or to the starting of the core, but was caused by the general pressure of the punch on the body of the metal over the hole in the die.

2. The next bar was punched to a depth of $1\frac{1}{8}$ inches, and on being treated with acid, as before, it showed the form of Fig. 8. We find that the mark on the under face now projects $\frac{1}{16}$ of an inch, and

that the lowest layers are slightly disturbed; therefore, the point of maximum flow has been reached, and must lie between $\frac{7}{8}$ inch and $1\frac{1}{8}$ inches in depth, or, in other words, the starting point of the core, for the above thickness of iron, is about 1 inch from the upper surface of the bar.

3. In the third experiment, under exactly the same conditions, the punch was entered into the bar to a depth of $1\frac{1}{4}$ inches. Referring to Fig. 9, we see that here the core has started, and is projecting $\frac{1}{8}$ of an inch below the under face of the block. The layers are all bent, the lower ones being the least, and the upper ones, where the punch has passed, showing the flow, as in the case of complete punching represented in Fig. 3. We also see that the core has already

FIG. 7.

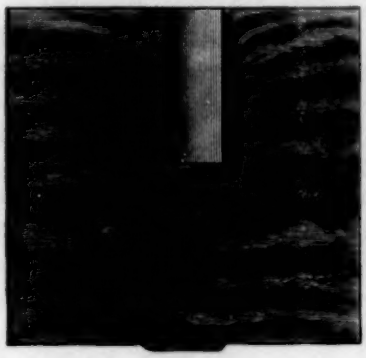
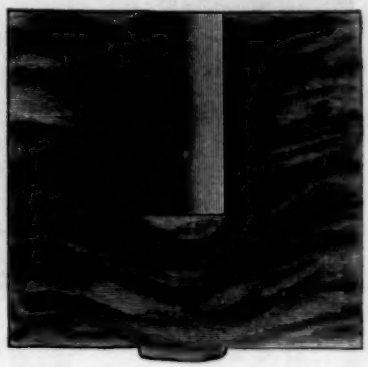


FIG. 8.



attained its least thickness, being but $\frac{3}{4}$ of an inch in depth, which is about that of the core represented in Fig. 4.

4. In the fourth and last experiment, the punch was stopped at a depth of $1\frac{1}{2}$ inches, the resulting block being shown in Fig. 10. The core projects from the bottom face nearly $\frac{1}{2}$ inch, and measures, as before, almost $\frac{3}{4}$ inch in depth. The layers, in this case, are all severed, and the line of parting of the core from the block is plainly visible. The force necessary to finish the punching is very small, compared to the total force required to punch such thickness of metal. The point of the maximum flow of metal is visible to the eye when watching the action of the machine, which gives a slight jar,

starting downwards, as if relieved from great pressure, when the core just starts, or wholly divides the under surface of the block.

That these experiments prove the flow of metal to occur in cold punching, and at great depths, is undeniable, but whether it will in the future be practically applied to take the place of partial drilling, is a matter which time only can determine.

This property of flowing in downward curves is highly advantageous to the quality of the nut, as, on being tapped, the thread is made up of several layers, instead of one, and the strain which comes on them is taken on end instead of across the grain, thus giving the iron

FIG. 9.

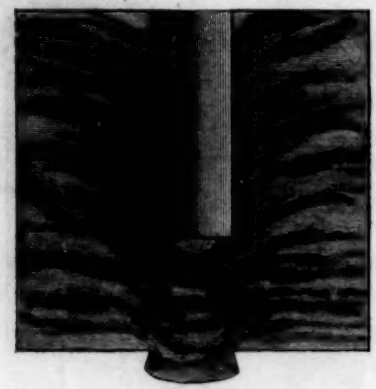
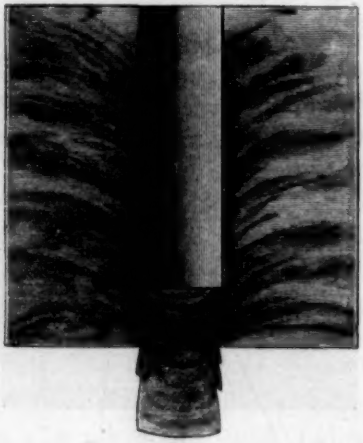


FIG. 10.



a much greater resisting power. The process of punching these thick bars does not depend for its successful performance upon the time taken, but upon the accuracy and power of the machine, and the quality of the punch. The element of time is introduced only so far as the wear and tear of the tools and the machinery determine it; as for the flow, that remains the same, whether the motion is fast or slow.

STEVENS INSTITUTE OF TECHNOLOGY,

Hoboken, N. J., Jan., 1878.

RADIATION OF HEAT FROM STEAM-BOILERS, PIPES, ETC.

By Chief Engineer ISHERWOOD, U. S. Navy.

Experiments made at the "Vulcan Works," Baltimore, Md., to ascertain the law governing the loss of heat by radiation from the plate iron surfaces of steam-boilers, steam-pipes, etc., in function of difference of temperature between that of the internal steam and that of the external still air. Also, the quantity of heat in Fahrenheit units thus radiated per hour per square foot of surface per degree Fahrenheit difference of temperature on the opposite sides of the naked metal. Likewise, to ascertain the decrease that may be effected of this radiation by clothing the metal with hair-felt of different thicknesses.

The experiments hereinafter described were made in 1863, 1864, and 1865, by the writer, who, being at that time the Chief of the Bureau of Steam Engineering in the Navy Department, had the designing and repairing of the machinery of most of the enormous number of steamers belonging to the United States Navy during the war of secession. Among the items of expense, the cost of hair-felt for covering boilers was very great, and he instituted these experiments for the purpose of discovering the most profitable thickness of felt to be employed; that is to say, the thickness, whose cost, taken in connection with the cost of the fuel it could save during the time it lasted, would be a minimum.

A favorable opportunity for making the experiments occurred at the "Vulcan Works," in the City of Baltimore, where the repairs of the machinery of the North Atlantic Fleet were principally made, and where a staff of expert naval engineers was constantly employed. The writer having constructed the apparatus and organized the experiments, all that the engineers had to do was to conduct them accordingly, and fill up the columns of a printed log or tabular record, furnished them, with the quantities observed. These logs were forwarded to the writer at the close of each experiment, and from them he generalized the following results:

In steam engineering it is of considerable importance to know the quantity of heat radiated from the external surfaces of steam-boilers, steam-pipes, etc., both when naked and when clad with hair-felt, the latter being the usual non-conductor employed to diminish the escape of the heat. The quantity of heat thus lost by the radia-

tion from the naked metal, will evidently be, *ceteris paribus*, directly as the extent of surface exposed, and as some function of the difference between the temperature within the boiler or pipe and that of the air surrounding it; and, when the metal is covered, this quantity will be diminished in some function of the thickness of the enveloping felt. The object of the following experiments, therefore, was to ascertain these two facts for the mean conditions of ordinary steam-engineering practice.

The metal selected was plate iron of the average kind used in boiler making, and having a thickness of five-sixteenths of an inch. The experiments were first directed to ascertain the number of Fahrenheit units of heat radiated per hour in still air, from a square foot of the naked metal per degree Fahrenheit difference of temperature on its opposite sides, for different intervals of temperature thereon; and, afterward, to ascertain, in an exactly similar manner, the number of Fahrenheit units of heat radiated per hour in still air per degree Fahrenheit difference of temperature between that of the steam within the boiler or pipe and that of the still air surrounding it, for different intervals of these temperatures, from a square foot of the metal covered with different thicknesses of hair-felt.

The experiments were made by means of the apparatus described below, and in the manner thereafter narrated.

Description of the Apparatus.

The radiator consisted of a rectangular box, made of the ordinary plate iron used for boilers, and five-sixteenths of an inch in thickness. The interior dimensions of its sides were 72 inches long and 36 inches wide. It was 2 inches broad on the interior, and its sides were braced square across every 9 inches, by the ordinary $\frac{1}{8}$ of an inch diameter socket bolts employed for bracing the flat water-spaces of boilers. Each side was composed of a single plate, and the box was formed by riveting the plates together. The interior superficies of the box was 39 square feet, and the exterior superficies was 40·926 square feet, the ratio of the two superficies being respectively as 1·0000000 to 1·0493846. The inner capacity of the box was 3 cubic feet. These measurements are for the temperature of 60 degrees Fahrenheit.

The radiator was placed on wooden supports, with one of the diagonals of its sides vertical, so that the upper corner of the box

formed an apex, and the diagonally opposite lower corner formed a point of lower depression than any other in the box. In this position its apex communicated by a steam-pipe of 2 inches outside diameter, with the upper portion of the steam-drum of the boiler furnishing steam for the engine of the "Vulcan Works." The apex of the box was placed 3 feet in height above the top of the steam-drum, so that any water of condensation formed in the steam-pipe would, by draining back to the boiler, by gravity, be prevented from entering the radiator. To render the quantity of such water of condensation a minimum, the steam-pipe was permanently covered with hair-felt 4½ inches thick. In the steam-pipe, and as close to the radiator as possible, was placed a stop-cock to be used as a throttle-valve to control the admission of the steam to the radiator, and maintain it therein at any desired pressure, not exceeding that in the boiler. On one side of the radiator, and just below its apex, was placed a carefully tested spring-gauge, to indicate the pressure of the steam within the radiator.

From the point of lowest depression of the box, proceeded a leaden pipe of one inch outside diameter, which was coiled into a tank through which passed continuously a stream of cold water drawn from the pipes of the city water-works. By properly regulating the quantity of cold water passing through the tank, the water of condensation from the radiator traversing the coil of pipe, could be delivered at about the temperature of the atmosphere into the closed vessel provided to receive it, and in which it was carefully weighed at regular intervals. By means of this arrangement, as little of the water of condensation as possible was lost by evaporation into the atmosphere. A stop-cock was placed in the leaden pipe as near the radiator as possible, to control the delivery of the water of condensation, and prevent the escape of any steam. A vertical glass water-gauge, one end of which communicated with the side of the radiator at its lowest point, while the other communicated with that side 18 inches higher, constantly denoted the water level within the radiator, which was kept at the lowest point possible without risking the escape of steam.

Although the radiator was placed in the still air of a large enclosed shed, yet it was not in confined air, as the shed had many and large openings, so that the air set in motion by the heat received from the radiator, could pass off and be renewed without restriction. And to

shield the radiator from all air currents otherwise caused, and from all accessions of heat externally, it was enclosed by wooden partitions, open above and below. The air had thus free ingress and egress around the radiator, but with no greater velocity than due to its heating by the radiator. The purpose of the entire arrangement was to place the radiator as nearly as practicable in the same surroundings as steam-boilers have in the holds of vessels. The temperature of the inflowing air was taken by two thermometers, hung outside of the partitions, and its pressure was taken by a barometer.

The covering employed was the ordinary cow hair-felt, manufactured for clothing steam-boilers, weighing one pound per square foot, when 1½ inches thick. It was stitched tightly over the radiator, so as to be in contact at all points, thereby preventing air-spaces, or air circulation, between the felt and the radiator. The thickness of the felt experimented with, was ¼ inch, ½ inch, ¾ inch, 1 inch, 2 inches, 3 inches, 4½ inches, 6 inches, and 7½ inches.

Manner of making the Experiments.

The steam with which the radiator was supplied, was drawn from the boiler of the "Vulcan Works," a sufficient pressure being kept in it for that purpose while the works were not in operation.

Each experiment continued 72 consecutive hours, during which exactly the desired steam-pressure was maintained in the radiator by an assistant engineer, who watched the steam-gauge and regulated by hand the throttling-cock in the steam-pipe to produce that effect. Enough water being at the same time passed through the refrigerating tank from the pipes of the city water-works, to reduce the temperature of the water of condensation discharged from the radiator to about that of the atmosphere. After the conditions were made uniform, the apparatus, in order that every portion might become in harmony with them, was operated for an hour before the experiment was held to commence.

For each experiment a tabular record was kept, in which were entered at the end of each hour the temperature of the air as given by the mean of the two thermometers, and the height of the barometer. The weight of the water of condensation was also entered at each time of weighing. Every care was taken to secure accuracy in the instruments used, and in their use. The boiler-pressure being limited to 65 pounds per square inch above the atmosphere, the

highest pressure used in the radiator was 60 pounds; the other pressures used therein were 50 pounds, 40 pounds, 30 pounds, 20 pounds, and 10 pounds per square inch above the atmosphere. The experiments were thus made for regular differences of 10 pounds per square inch in the pressure of the steam; and each set of experiments was six in number.

With the radiator naked, four sets of experiments were made, each set being an exact repetition of the others, so that the aggregate duration of the four experiments, with steam of 10 pounds pressure per square inch above the atmosphere, was 288 hours; of the four with 20 pounds pressure, 288 hours, and so on of the rest, each pressure being experimented with during 288 hours, making a total of 1728 hours with the naked radiator.

With the radiator covered with hair-felt $\frac{1}{4}$ of an inch thick, one set of six experiments was made with steam of respectively 10, 20, 30, 40, 50, and 60 pounds pressure per square inch above the atmosphere; the aggregate duration being 432 hours. And precisely the same number of experiments were made, and with the same steam-pressures, with the radiator covered with hair-felt of $\frac{1}{2}$ and of $\frac{3}{4}$ inch thickness; the aggregate duration of these experiments with each thickness being 432 hours.

When the radiator was covered with hair-felt of 1 inch thickness, two sets of six experiments each were made, the one set a duplicate of the other, the same steam-pressures of 10, 20, 30, 40, 50, and 60 pounds per square inch above the atmosphere being used in each, making the aggregate duration 364 hours.

With the radiator covered with hair-felt of respectively 2, 3, $4\frac{1}{2}$, 6, and $7\frac{1}{2}$ inches thickness, one set of six experiments was made with each thickness; the same steam-pressures of 10, 20, 30, 40, 50, and 60 pounds per square inch above the atmosphere being used with each thickness. The aggregate duration of the experiments with each thickness was 432 hours.

There were thus made in all 84 experiments, extending in the aggregate through 6048 hours.

Determination of the Results.

In ascertaining the number of Fahrenheit units of heat radiated per square foot of surface, the interior dimensions of the box or radiator were used, and these dimensions were calculated for each

difference of temperature, as the temperature varied in each experiment; that is to say, the temperature of the interior superficies of the box was assumed to be the same as that of the contained steam, and its dimensions, at the standard temperature of 60 degrees Fahrenheit, were increased by the amount of the dilatation due to the temperature of the steam within. The temperature of the steam normal to the experimental pressure, was taken from Regnault's experiments. The effect of the barometric variation was also included in the calculations, the number of units of heat radiated being corrected to what they would have been, had the pressure of the air been equal to the standard of 29·92 inches of mercury, at 32 degrees Fahrenheit. This correction was made in the direct ratio of the density of the air.

The number of units of heat radiated during each experiment, was calculated, with the above corrections, from the weight of the water of condensation discharged from the radiator, and from the latent heat of steam of the experimental pressure, being simply the product of these two factors. As the steam-pressure varied in the different experiments, and as the latent heat varies with the pressure, it was necessary to substitute the number of units of heat radiated in equal time for the pounds weight of steam condensed during that time, as the measure of the radiation; consequently, for each experiment these units were separately calculated per square foot of radiating surface and per hour, and these quantities being divided by the difference between the Fahrenheit temperature of the steam inside the radiator and that of the air outside, gave the final result in number of Fahrenheit units of heat radiated per square foot of surface per hour per degree Fahrenheit difference of temperature on the opposite sides of the radiating surface.

The extremely near equality of these final results given by each set of the different experiments under very considerable inequality of condition, shows at a glance that, *ceteris paribus*, within the limits of the experimental temperatures, *the quantity of heat radiated in equal time from the same surface with different temperatures on its opposite sides, was in the direct ratio of their difference.*

A straight line being taken for a base, and divided by scale into abscissæ, corresponding in lengths to the different thicknesses of hair-felt with which the radiating surface was covered, and from the end of each abscissæ a perpendicular being erected on which was laid off by scale, as an ordinate, the mean final result for each set of

experiments in Fahrenheit units of heat radiated per hour per square foot of surface per degree Fahrenheit difference of temperature on the opposite sides of the surface, a graphic curve, passed through the free ends of these ordinates, was found to be such that it coincided almost exactly with the law that the number of units of heat radiated was in the inverse ratio of the square roots of the thicknesses of felt employed from the thickness of 7½ inches up to the thickness of 1 inch, from which latter thickness up to the naked metal, the curve, though a fair one, followed no regular law. A curve laid out on the same scale, with the ordinates proportional to the square roots of the abscissæ, scarcely varied the thickness of a pencil-line from the graphic curve obtained as above described for the experiments with felt of various thicknesses between 7½ inches and 1 inch.

The term "radiation" has thus far been applied for the sake of convenience to the process by which the heat left the surface, but in fact the heat escaped by means of two entirely distinct processes, acting independently of each other, and simultaneously, the one radiation proper, the other conduction. By means of the first, a certain portion of the escaping heat was radiated through the air heating it to only an insensible degree, while by means of the last, the remaining portion of the escaping heat was transferred by conduction from the hot metallic surface to the particles of cool air resting upon it, which, as soon as heated by the contact, were pushed out of place by other particles of cool air, to be in their turn heated and displaced, the movement being a result of the lessened density of the air after it is heated. Part of the escaping heat was thus taken up by the air, and the remainder by the distant bodies on which the radiant heat impinged These remarks apply in their integrity to the case of the naked metal alone, but when the metal is covered with hair-felt, only the hairs of which, considered separately, have any conducting power, the interstitial air being sensibly destitute of that quality; and where it is considered that by the process of felting short hairs are merely loosely interlaced, touching each other only at a few points, whereby those on the exterior surface can be scarcely said to have any connection with those on the interior surface, which latter alone are in contact with the metal, and receive heat from it by conduction; it will be seen how very little heat can be transferred from the metal to the outside hairs by the conducting power of the hairs themselves. Whatever increase of temperature, therefore, the

outside hairs receive, is not from the metal, which they do not touch, but from the air by which they are surrounded, and which has been heated by conduction; consequently, almost all the heat lost by the metal has gone in the first instance to heat the interstitial air by conduction, a merely infinitesimally small portion being expended upon the hairs by conduction, and by them radiated through the atmosphere to the nearest objects.

Thus, in the case of the metal having a hair-felt covering, sensibly the entire loss of heat is by conduction alone, and is expended in heating the interstitial air. The quantity of such air heated in a given time, will depend on the rapidity with which it can be replaced, and that rapidity is evidently a function of the thickness of the felt; for the velocity with which the heated air is expelled from the interstices by the greater density of the outside cool air, will be regulated by the number of hairs or resistances which impede the movement, and this number will be directly as the thickness of the felt. Now, as soon as uniformity of movement is established in the heated interstitial air, the pressure causing it and due to the greater density of the outside cool air, will remain constant, and as with constant pressure the velocity of air moving against different resistances is inversely as the square roots of those resistances, that velocity, in the case of our problem, will consequently be inversely as the square roots of the number of opposing hairs, or inversely as the square roots of the thickness of the felt. And as the quantity of heat carried off from the metal by the interstitial air in equal time, is measured directly, *ceteris paribus*, by the velocity with which that air moves over the metallic surface, *the quantity of heat lost in equal times by the metal*, ceteris paribus, *when covered with different thicknesses of felt, will be inversely in the ratio of the square roots of these thicknesses.* Such is the ratio which was experimentally found to exist for all thicknesses of felt over one inch, but for thicknesses of less than one inch the experimental ratio was higher, the loss of heat with such small thicknesses being greater than inversely in the proportion of the square root of the thickness. This was doubtless owing to the fact that a thickness of one inch was required to accumulate a sufficient number of hairs to completely intercept the radiant heat proceeding from the metal, less thicknesses allowing an escape of heat by direct radiation through the interstices, as well as by the conduction of the interstitial air. The experiments, then, not

Table 1.

Showing the loss of heat per hour in Fahrenheit units,[1] per degree Fahrenheit difference of temperature between the temperature of the steam upon one side of a square foot of boiler-plate iron 5-16 of an inch thick, and the temperature of the still air upon the other side, when naked, and when covered on the air side with different thicknesses of cow-hair felt weighing one pound per square foot for the thickness of 1½ inches:

Thickness in inches of the cow-hair felt on the air side of the boiler-plate iron.	Number of Fahrenheit units[1] of heat lost per hour per square foot of boiler-plate iron 5-16 of an inch thick, per degree Fahrenheit difference of temperature between that of the steam on one side of the metal, and that of the still air upon the opposite side.	Thickness in inches of the cow-hair felt on the air side of the boiler-plate iron.	Number of Fahrenheit units[1] of heat lost per hour per square foot of boiler-plate iron 5-16 of an inch thick, per degree Fahrenheit difference of temperature between that of the steam on one side of the metal and that of the still air upon the opposite side.
Naked.	2·933067200000000	4·00	0·153527736250000
0·25	1·054071025000000	4·25	0·148499160098979
0·50	0·572864687500000	4·50	0·144747361312670
0·75	0·412462575000000	4·75	0·141307301065023
1·00	0·307055472500000	5·00	0·137319380496593
1·25	0·274638760921693	5·25	0·134089991829888
1·50	0·250709717124564	5·50	0·130918876690775
1·75	0·232112059255524	5·75	0·128050971134813
2·00	0·217120939617333	6·00	0·125325955324240
2·25	0·204703648333028	6·25	0·122822189000000
2·50	0·194198911355266	6·50	0·120437220476490
2·75	0·185161460871052	6·75	0·118185716224532
3·00	0·177278540008271	7·00	0·116056073492882
3·25	0·170323696621130	7·25	0·114037556701880
3·50	0·164128026933513	7·50	0·112120797096856
3·75	0·158546362813801		

[1] The Fahrenheit unit of heat is the quantity of heat required to raise the temperature of one pound of water at 32 degrees on Fahrenheit's scale to 33 degrees.

only give the loss of heat quantitatively due to the different thicknesses of the felt, but furnish likewise the physical proof of the theoretical law regulating that loss in function of the thickness of the felt.

The figures in Table No. 1 show, by mere inspection, the *relative* loss of heat when the metal is naked, and when it is covered with felt of different thicknesses, *for the same steam-pressure and for the same air-temperature.* But they can also be employed to determine, in any given case, the absolute quantity of heat lost for any pressure of steam and temperature of air. For example: Suppose a naked boiler, the surface of whose shell is 450 square feet, the air temperature upon its outside 60·3 degrees Fahrenheit, and the steam-pressure within it 60 pounds per square inch above the atmosphere, the temperature normal to which is 307·3 degrees Fahrenheit; then its loss of heat per hour will be $(2{\cdot}9330672 \times 450 \times 307{\cdot}3^\circ - 60{\cdot}3^\circ =)$ 326010·42 Fahrenheit units. Or, as the latent heat of steam of this pressure is 897·74 Fahrenheit units, the weight of steam that will be condensed per hour, to water of the temperature 307·3 degrees Fahrenheit, will be $\left(\frac{326010{\cdot}42}{897{\cdot}74} =\right)$ 363·145 pounds; equivalent to a bulk of $\left(\frac{363{\cdot}145}{62{\cdot}388} \times 349{\cdot}13 =\right)$ 2032·2 cubic feet, at the pressure of 60 pounds per square inch above the atmosphere. The proper air temperature to be taken is that of the external atmosphere, not that of the fire-room. In general, let

c be the tabular constant in Fahrenheit units of heat.

a be the area in square feet of the surface of the boiler shell.

t be the temperature of the steam within the boiler.

t' be the temperature of the external atmosphere.

h be the latent heat of the steam within the boiler in Fahrenheit units.

v be the volume of steam of boiler pressure, relatively to the volume of water at the temperature 39 degrees Fahrenheit, from which the steam was generated.

62·388 be the weight in pounds of a cubic foot of water, at the temperature of 39 degrees Fahrenheit; then in general,

$c \times a \times (t - t') =$ the loss of heat per hour in Fahrenheit units.

$\frac{c \times a \times (t - t')}{h}$ = the weight in pounds of steam of the temperature t, condensed per hour, to water of the same temperature.

$\frac{c \times a \times (t - t')}{h} \times \frac{v}{62{\cdot}388}$ = the bulk in cubic feet of steam of the temperature t, condensed per hour, to water of the same temperature.

When the weight of steam of a given pressure evaporated per hour in the boiler, and the temperature of the feed-water, are known, the *proportion* of the heat contained in the steam, which is lost by external radiation from the boiler-shell, can easily be calculated, the *absolute* quantity so lost per hour having been ascertained from the previous data.

The weight of steam evaporated per hour can be obtained directly by previous measurement, in a tank, of the feed-water pumped into the boiler; or it can be obtained, indirectly, from the weight of fuel consumed per hour, and its economic vaporization per unit of weight; in practice, these latter data are most readily available. Now with the average proportions of practice, the grate-surface of a boiler is about one-eighth of the surface of its shell, so that in the case of the example of a boiler with 450 square feet of shell surface, the grate surface would be about 56 square feet. Taking the average rate of combustion of anthracite at 14 pounds per square foot of grate-surface per hour, and its economic vaporization per pound at 8 pounds of water from the temperature of 100 degrees Fahrenheit, and under the pressure of 60 pounds per square inch above the atmosphere, there would be evaporated per hour ($56 \times 14 \times 8 =$) 6272 pounds of steam, to each pound of which the fuel had imparted ($1207{\cdot}68 - 100{\cdot}07 =$) 1107·61 Fahrenheit units of heat, making the quantity of heat imparted to the steam per hour ($6272 \times 1107{\cdot}61 =$) 6946929·92 Fahrenheit units, of which the 326010·42 Fahrenheit units lost per hour, by radiation from the naked shell, are $\left(\frac{326010{\cdot}42 \times 100}{6946929{\cdot}92} =\right)$ 4·69 per centum.

Now as the loss of heat per hour, by radiation, will be the same, so long as the air temperature outside the boiler, and the steam temperature inside the boiler, remain the same, let the weight of steam evaporated in the boiler per hour be what it may, there follows that ***the per centum of the heat lost by radiation, other things equal, will be, inversely, in the ratio of the weight of steam evaporated in equal times.*** Thus, in the case of the previous example, if, instead of the

6272 pounds of steam evaporated per hour, only 3136 pounds had been evaporated, or one-half, then, as the absolute loss by radiation continues the same, its per centum would have been doubled, or become 9·38, instead of the 4·69. On the contrary, had the weight of steam evaporated per hour been one-half more, or 9408 pounds, instead of the 6272 pounds, other things equal, the constant loss by radiation would have amounted to 3·13 per centum of the total heat in the steam above the temperature of the feed-water, instead of the 4·69 per centum, and so on.

The foregoing calculations are, it will be observed, for naked metal—for a boiler without any covering whatever—and show that, under the average conditions of practice, and for a steam-pressure as high as 60 pounds per square inch above the atmosphere, the loss of heat by radiation is less than 5 per centum. This is the margin on which a saving is possible by the application of felt or other covering. Had the boiler been covered with felt 1½ inches thick, the 4·69 per centum loss by radiation, when 6272 pounds of steam were evaporated per hour, would have been reduced, in the ratio of the tabular constants, 2·9330672 and 0·2507097, and become only 0·40 per centum—that is, four-tenths of one per centum of the total heat imparted to the steam. It is only upon this very small quantity that any saving can be effected by the application of additional felt, or of any other non-conductor. Hence, a considerable difference in the non-conducting efficiency of different kinds of covering, having equal thickness, weight or cost, scarcely affects, to a sensible degree, the per centum of heat lost by radiation from boilers; probably not to the extent of the one-thousandth part of the total heat in the steam.

In the following Table, No. 2, will be found the loss of heat by conduction from boilers covered with hair-felt 1½ inches thick, and having 8 square feet of shell-surface to each square foot of grate-surface, in per centum of the total heat imparted to the steam; the temperature of the feed water being taken at 100 degrees Fahrenheit, and that of the external air at 60 degrees Fahrenheit. The determinations have been made for anthracite burned at the rates of 4, 8, 12, 16, 20 and 24 pounds per square foot of grate per hour, and for steam-pressures of 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 pounds per square inch above the atmosphere. The boiler is supposed to have 25 square feet of water-heating surface to each square foot of grate, and to have an aggregate cross section of tubes for draught, or calorimeter, equal to one-eighth of the grate surface.

TABLE 2.

Steam-pressure in boiler in pounds per square inch above the atmosphere.	PER CENTUM OF THE TOTAL HEAT IMPARTED TO THE STEAM ABOVE THE TEMPERATURE OF THE FEED-WATER, LOST BY CONDUCTION.					
	Burning 4 pounds of anthracite per square foot of grate surface per hour. Evaporative efficiency of the pound of anthracite, 9·33 pounds of water from 100° F.	Burning 8 pounds of anthracite per square foot of grate surface per hour. Evaporative efficiency of the pound of anthracite, 9·20 pounds of water from 100° F.	Burning 12 pounds of anthracite per square foot of grate surface per hour. Evaporative efficiency of the pound of anthracite, 8·47 pounds of water from 100° F.	Burning 16 pounds of anthracite per square foot of grate surface per hour. Evaporative efficiency of the pound of anthracite, 7·30 pounds of water from 100° F.	Burning 20 pounds of anthracite per square foot of grate surface per hour. Evaporative efficiency of the pound of anthracite, 6·50 pounds of water from 100° F.	Burning 24 pounds of anthracite per square foot of grate surface per hour. Evaporative efficiency of the pound of anthracite, 6·06 pounds of water from 100° F.
10	0·8672	0·4498	0·3257	0·2834	0·2530	0·2276
20	0·9775	0·4957	0·3589	0·3124	0·2806	0·2559
30	1·0476	0·5312	0·3847	0·3347	0·3007	0·2688
40	1·0826	0·5588	0·4047	0·3524	0·3164	0·2828
50	1·1556	0·5860	0·4243	0·3693	0·3318	0·2965
60	1·1992	0·6081	0·4403	0·3832	0·3442	0·3077
70	1·2384	0·6280	0·4547	0·3957	0·3556	0·3178
80	1·2744	0·6462	0·4679	0·4072	0·3659	0·3270
90	1·3063	0·6624	0·4796	0·4174	0·3750	0·3351
100	1·3401	0·6795	0·4920	0·4282	0·3847	0·3439

In Table No. 2, the per centum of the heat imparted by the fuel to the steam, which is lost by conduction, has been calculated for six rates of combustion increasing by equal quantities, instead of for six weights of steam increasing by equal quantities in equal time, because the one is not a measure of the other, and the rate of combustion is the most convenient reference for engineers. The economic vaporization by the unit weight of fuel decreases in a boiler of the supposed proportions as its rate of combustion is increased; for anthracite, this decrease is shown, for the assumed rates of combustion, by the quantities in the headings of the columns; which quantities are the means from a vast number of experiments.

The per centum in the columns shows how insignificant, under any condition of steam-pressure, is the loss of heat by conduction when the boiler is covered with $1\frac{1}{2}$ inches thick felt; for even with the low rate of combustion of 8 pounds of anthracite per hour per square foot of grate, and the high steam-pressure of 100 pounds per square inch above the atmosphere, the loss is only about two-thirds of one per centum of the fuel, which gradually diminishes to about one-third of one per centum as the rate of combustion increased to 24 pounds of anthracite per square foot of grate per hour.

For medium steam-pressures, say about 30 pounds per square inch above the atmosphere, this loss, with the 8 pounds per hour per square foot of grate of anthracite combustion, is but a little over one-half of one per centum of the fuel, falling to a little over one-fourth of one per centum when the rate of combustion rises to 24 pounds.

If the loss of heat that would take place with the boiler naked instead of being covered with $1\frac{1}{2}$ inches thick felt, is required to be known for the tabular conditions, it is only necessary to multiply the quantities in the columns of Table No. 2, by $\left(\frac{2{\cdot}933067200}{0{\cdot}250709717} = \right)$ 11·6990567, in order to obtain that loss in per centum of the heat imparted by the fuel to the steam.

From the experimental data there can also be determined the weight and bulk of air which can be raised one degree Fahrenheit in temperature, by the heat radiated per hour from one square foot of naked boiler-plate $\frac{5}{16}$ inch thick, per degree Fahrenheit difference of temperature between that of the steam on one side of the plate and that of the air on the opposite side.

The weight of a cubic foot of air in latitude 45 degrees, at the sea-level, under the pressure of 29·92 inches of mercury at the temperature of 32 degrees Fahrenheit, and with the temperature of 60 degrees Fahrenheit, is 0·076 pound avoirdupois. This air contains the average proportions of carbonic acid gas and aqueous vapor; and has under constant pressure, the specific heat 0·238. Now, as by the experimental data, the quantity of heat imparted to the air by each square foot of radiating boiler-plate per hour per degree Fahrenheit difference of temperature between that of the steam and that of the air on opposite sides, was 2·9330672 Fahrenheit units, or, in other words, a quantity sufficient to raise the temperature of 2·9330672 pounds of water at 32 degrees Fahrenheit one degree, and as the specific heats of this water and air compare as 1·000 and 0·238 respectively, this

quantity of heat will raise the temperature one degree Fahrenheit of $\left(\frac{2{\cdot}9330672}{0{\cdot}238} =\right)$ 12·3238 pounds of air occupying 162·1553 cubic feet. As the specific heat of air does not vary sensibly with its temperature, these quantities will be in the direct ratio of any other number of degrees difference of temperature, and can be employed to determine the quantity of radiating surface with given temperatures of steam and air upon its opposite sides, that is required to heat per hour any desired weight or bulk of air from one given temperature to another.

Suppose, for example, the temperature of the steam on one side of the radiating surface to be 260 degrees Fahrenheit, corresponding to a pressure of 20·8 pounds per square inch above the atmosphere, and the temperature of the air flowing upon the other side to be 60 degrees Fahrenheit, it is desired to know the number of square feet of radiating surface required to heat to the temperature of 70 degrees Fahrenheit, 1500 cubic feet of this air per hour, which are about the volume necessary to be supplied to each man on the berth deck of vessels in order to remain salubrious.

The difference between the temperatures on the opposite sides of the radiating surface being $(260° - 60° =)$ 200 degrees Fahrenheit, each square foot of that surface will heat per hour $(162{\cdot}1553 \times 200 =)$ 32431·06 cubic feet of air, 1 degree Fahrenheit; or, as the air is to be heated $(70° - 60° =)$ 10 degrees, it will heat per hour that number of degrees $\left(\frac{32431{\cdot}06}{10} =\right)$, 3243·106 cubic feet. Consequently, $\left(\frac{1500{\cdot}}{3243{\cdot}106} =\right)$ 0 4629 is the fraction of a square foot of radiating surface required, under the conditions, to heat per hour 1500 cubic feet of air 10 degrees Fahrenheit; or, in other words, to supply, at the proper temperature, the proper bulk of air per hour for one man.

As the weight of a given bulk of air varies with the temperature, and as the number of degrees through which it is to be heated to the same constant temperature of, say, 70 degrees Fahrenheit, varies with its initial temperature, each case, even with a constant difference between the temperatures on the opposite sides of the radiating surface, evidently forms a distinct problem requiring its own numerical solution; but the process will be the same as shown above, and only requires the substitution of the proper numbers.

ON THE RELATION OF MOISTURE IN AIR TO HEALTH AND COMFORT.[1]

By Robt. Briggs, C. E., Cor. Mem. Am. Inst. of Architects, etc.

[Continued from Vol. lxxv, page 93.]

§ It has been shown how nearly impracticable it is to procure, in winter, with the average temperature of winter, which is 34°, a summer temperature and humidity in our houses. The difficulties of effecting this with 34° for the temperature of the external air are enhanced greatly, as the minimums of cold are reached, and at zero the production of a summer air in a house or place of residence may be claimed to be impossible. If the effect of the changes of out of door temperatures and humidities, which can happen with, at the worst, eight to twelve hours of change, and which, on the average, gives twenty-four to seventy-two hours of interval, is as objectionable; what words can express the effect of the mere passing from a room at summer humid warmth to the open anhydrous air at zero? There are few readers of this paper, who have not tried the experiment of leaving some crowded hall, where the closed doors and windows, and many breaths, had made an approach to the summer condition, and felt the cold air of winter at the bottom of the lungs, as the inactive membrane parted with its unexpected supply of moisture to the anhydrous air. At whatever temperature or moisture condition air be inhaled, it will be exhaled at 90°, and laden with moisture nearly to the point of saturation. Of the heat given out by the lungs, that which proceeds from evaporation is generally largely in excess of what is required to impart heat to the air. Even in the extreme case of breathing air at —40° (or the temperature when mercury freezes, which the writer once observed at Vassalborough, Maine), the heat of evaporation of moisture from the lungs is but a little greater than that for heating the air, being 2·22 units in one case, to 2·18 units in the other, per cubic foot of exhaled air. The skin gives out its heat through insensible perspiration, or through heat imparted to air, in similar, if not the same, proportion.

The establishment of a regime of evaporation from the lungs or skin —of a constancy of secretions—appears to be more essential than the establishment of a uniform temperature, either of the air of respiration or of contact with the person. The stability of the moisture

[1] Paper read before the Am. Institute of Architects, at Boston, Oct. 18th, 1877.

condition, whether in the external air from time to time, or between inside and outside of the room, is what is desirable for health; and this stability, from inside to outside of room, is what we must maintain if we are to live in active, healthful life in our climate. The transfer of heat through the skin or membranes is merely conductive, not involving organic action; while the supply of moisture incident to the maintaining of evaporation, brings into service, vessels, ducts or pores, whose healthful action depends, in great measure, on the regularity and continuity of the said service. This hypothesis will explain at once the healthfulness of the climate of Florida or that of Minnesota in cases of pulmonary disease, and in other parts of the country will account for the prevalence of colds and coughs or the occurrence of rheumatic affections. The diseases of the changeable climate and water-laden winds of our colder Eastern states are bronchial and pulmonary; and (without desiring to intrench on the province of the medical profession, whose known duty at all times it has been to find the cause of disease) it may be safe to attribute them, to a great extent, to the effect of alternate dry and damp air on the evaporating surface of the lungs when the skin has the protection of clothing to keep it warm. The diseases of the warmer mountain-sides of our Middle states, are rheumatic, and may be attributed to the same cause operating, by warm currents of air, on the less unprotected skin.

Beside this view it can be averred that, for the resident or native of any country, there will have established, as a habit, a connection of moisture of air relative to its temperature which is national, so to speak, in which the *variations* of humidity and heat are accepted as a general average. Thus, the American in England is chilled to great discomfort by the low temperature endured by Englishmen, whose systematic evaporation provides for small loss of heat; while the Englishman in America finds a suffocating heat in the dwelling of the American, from the fact that his lungs and skin do not afford the moisture requisite for evaporation and consequent dispersion of heat. A long residence, often two or more years, is needed before the system of either is adapted to the novel condition.

§ Although somewhat late in the course of this argument, and perhaps somewhat elementary as information, it may be well to state the physical laws of the relation of moisture to air. The property of water is to possess in contact with itself, at any and all temperatures, from the boiling point downwards, an atmosphere of vapor,

which vapor has an elastic force, or exerts a pressure bearing some definite relation to the sensible temperature of the water and of itself. The English measures of this elastic force are generally expressed in inches of height of a mercury column, in the same way as shown by an English barometer, which of course applies to any unit of surface, and may be transformed to pressure in pounds per square inch or square foot, by a similar process to what we use for atmospheric pressures. According to Regnault (as quoted in Guyot's tables), some of the elastic forces are as follows:

Degrees Fahrenheit.														
−30	−20	−10	0	10	20	32	40	50	60	70	80	90	100	212
0·0092	0·0163	0·0270	0·0434	0·0684	0·1078	0·1811	0·2476	0·3608	0·5179	0·7329	1·0232	1·4097	1·9179	29·922

Inches of Mercury Column.

From which it will be seen that the elastic force falls off rapidly with the temperature. At any given temperature, vapor, possessing the above value of elastic force, exists in the atmosphere as a part of its volume, *whenever there is water present to supply it*, and such an atmosphere is said to be saturated. When there is not sufficient water at hand to supply the vapor due to the temperature; what there is of vapor in the air is slightly superheated, as it accepts the temperature of the air and not that of its tension, but this effect is so small that it may be neglected. The air is then said to be dry; the usual way of estimating such dryness is by naming the percentage of vapor present, to that which would fully saturate the air at a given temperature. Dry air seeks moisture from any source, and the difference of elastic forces, between that of the vapor in the air at any time, and that of saturation of the same air, represents the *avidity* for moisture of such dry air as a species of partial vacuum.

Now the quantity of moisture as vapor accompanying a given quantity of air is neither increased nor diminished in the same air by heating or cooling it (of course in the latter case to the temperature when the air is saturated, below which point the moisture condenses). Hence it does not matter, so far as moisture is concerned, at what degree of heat we introduce the air for warming a room; if only the final temperature of the room be 70° or 80°, then the drying effect of the air of that room upon the persons occupying it, or its furniture, or its materials of construction, is that due to air of 70° or 80°, which air shall contain only the normal moisture of supply. In other

words, our hot air furnaces which supply air at 150° to 200°, do not (except, perhaps, close to the mouths of supply, before the heat is distributed) dry up wood-work or absorb any more moisture from the persons occupying a room, than those which give currents at 80° or 90°, provided the general temperature of the room is the same in both cases. But a yet more important truism can be stated, which is that the drying effect of air of a ventilated room at 70° or 80° which has received no increase of humidity in the hot air of ventilation from out of doors—air that has been warmed artificially from zero let us say—the drying effect of this heated air upon a person occupying it is very nearly the same as if he or she were to maintain the same temperature through active exercise and warm clothing out of doors. The exception expressed by "very nearly," relates to the clad portion of the body—the obstacle presented by the clothing to the free diffusion of aqueous vapor is more effective between the cold air which is but little warmed to demand moisture, and the skin which will give it out if the vacuum demands it, than between the arid air of the room which takes up every particle of moisture as it transpires through the clothing. As regards loss of moisture from the throat or lungs, however, there is absolutely no difference in breathing the air of the supposed room and that which is then found out of doors, although the one be at 70° to 80° and the other at zero; reiterating the former statement: "In either case the exhaled breath is at 90° as it passes out from the nostrils or lips, and is saturated or nearly saturated with moisture." No one ventures to assert that it is unhealthy, as an act of breathing, for the human race to breathe freely the coldest dry air of winter, because of the supplying of moisture to the anhydrous air. There is an evident fallacy in the assumption that it can be healthy to check instantly that copious secretion which has been supplying moisture to the fresh cold air of zero, by going into a room of summer hygrometric condition, or to demand such an effort of the tissue of the lungs suddenly by leaving such a room for the outer air. Fortunately, nature is more lenient than the theorists, and we do not get 70° to 80° with 70 per cent. of saturation in the most unventilated or uncomfortably heated houses, and with all efforts to the contrary, even 40 per cent. is of unusual attainment when the external air has a temperature of zero.

It must be admitted, however, that some small degree of hydration is a necessity for comfort, and with comfort for a demand, some reason

may be found to establish the healthfulness of the small supply. It is certain from all experience that from 5 to 10 per cent. of moisture can be added to air after it is heated, certainly with much relief, especially to the eyes, with apparently little harm, although such addition may make the occupant of a heated room a little delicate as to out-door exposure. Moisture may to some small extent be abstracted by the means of heating, especially when the heating is by stoves or hot air furnaces; at all events the presence of a sheet or surface of water over which the heated air is allowed to pass, is now a recognized means of supplying a small quantity of aqueous vapor to air of ventilation. But the quantity supplied in this way is very small in comparison with what is needed for complete "hydration," or even for what can be denominated "hydration" at all, in the sense of a summer condition. From an estimate based on several winters' experience, a vaporization of water which supplied a half grain of vapor per cubic foot of air introduced, when an increment of four to six grains for the same volume of air would be requisite to get the summer condition of humidity corresponding to the internal temperature, has proved sufficient to give a sensibly pleasant air, while the absence of this supply was at once perceptible in the house. A low pressure hot water apparatus, whose temperature never reached the boiling point, and rarely exceeded 180°, giving heat to a large volume of fresh air, which, at the mouths of supply to the rooms, was not much above 90° at any time, was the source of heat.

§ It is very difficult to find any hypothesis which will account for this requirement of a small supply of vapor with heated air, when we admit, or can demonstrate, that the sufficient quantity to the senses is so far below what is needed for hydration, and so independent from the moisture condition of the air; for nearly the same small quantity of vaporization seems desirable in air heated from any temperature. The explanation of the offensiveness of heated air currents has been sought with much diligence, and, at times, causes have been assigned with much positiveness. One of the earliest of these explanations (but one which yet finds supporters) was found in the substitution of transferred or convected heat by currents of air for the radiant heat of fire. Open fires were to be restored as the means of securing pleasant air. The healthfulness and comfort of our ancestors were to come back to their degenerate children. Gathered around a blazing fire, roasted on one side and frozen on the

other; restricted to one fire in the house, as all the others *would* smoke; the chamber-heating apparatus reduced to the warming-pan; victims of rheumatism, sciatica, tic-douloureux and ague—the diseases of fifty years ago—the good old times were to come back. Alas! there were obstinate innovators, and the world would not be convinced of the advantages of radiant heat as the sole means of warming.

This point being established, at a later time, surfaces at high temperatures for imparting heat to the air of a room, either by ventilating currents or direct heating, including all fire-heated surfaces, together with steam-heated ones, above the boiling point, or 212°, were utterly condemned. Somebody discovered burnt atoms of dust in heated air, and its destructive, pernicious effect on the health was at once apparent! But the comfort of the community some way overruled the theory, and hot-air furnaces, with admitted deficiencies in quality of air, met greater favor than ever. It is allowed, generally, that the expensive steam-heating apparatus is at once the more pleasant, controllable and durable; and that the yet more expensive hot-water apparatus, with its great volumes of low temperature currents of air, is the best of all means of heating. The cost in fuel by these several apparatuses becomes nearly the same, for equal effects, in warming of houses.

The next demonstration was the chemical one. An occult effect is most conclusively, if not convincingly, explained by an occult cause. Ozone is a favorable object to carry a theory, and it really is possible, if we knew anything definite and certain about the origin or the effect of ozone; some relation of this phenomenon of the requiring the evaporation of a small quantity of water, when heating air, might be traced. But no blinder pathway in science was ever opened than the ozone one. After this came Deville and Troost's discovery of the permeability of some metals, when heated at, or nearly at, red heat, to some of the gases. In the language of one of the most prominent writers on ventilation, this "explains the very injurious and even poisonous effects produced by the use of stoves in the rooms of a dwelling!"

The last resort of the unreasoning theorizer in physics is always to electricity, and efforts have not been wanting to show that either the presence or the absence of electricity, in some form or condition, ought to have something to do with the discomfort arising from heated air.

The only answer to this hypothesis is that heated air is equally oppressive in entire absence of water supply, whether highly electrical or otherwise; our vicissitudes of climate and of humidity enabling a test of electric condition in extreme cases. There are times in any winter, in the Northern states, when it is possible to gather enough electricity, by walking over a carpet, to make the spark from the finger which will light a gas-light. The quantity of water demanded at such times by a heating apparatus, is no greater than at other times. There is not the least positive proof of relation of electricity to the healthfulness of air. Altogether, the whole resolves itself to the reiteration of the bare fact, that it is comfortable to evaporate a small quantity of water in heated rooms, and that it can be done without marked injury to the occupants or to visitors. The quantity itself seems to be almost constant for all temperatures or hygromations of the air, and to be a slight addition only to the moisture in the normal air out of doors at any time.

§ The effect of draughts on currents of air upon any person exposed to them is materially modified by the hygrometric condition. In still air in winter the comfortable temperature of a room in general hygrometric condition has been stated at 70°, but a current of air upon the person at this temperature is uncomfortably cold from the rapid abstraction of heat, while in summer the same temperature, accompanied by the summer dew point, will be warm enough to demand light clothing, and a current of the same velocity will not be objectionable; in other words, draughts which cannot be tolerated in our houses in winter, become pleasant breezes in summer. Not only the speed or rate of velocity of the current of air is to be taken into account, but its avidity to take up moisture from the skin as indicated by its dew point. So long as the hygrometric condition of the air is such that will absorb moisture below 98°, a blast of it at some rate of current will be a cool one.

One fans himself in our climate, when the thermometer stands at 100°, with a sensation of relief. This feeling of cold, from air of high temperature, when in motion, proceeds from the rapid removal of the stratum of warm and nearly saturated air in contact with the person, and its replacement by fresh air, which is not only cooler, but which has not yet become saturated or charged with moisture by contact with a moist surface like that of the skin. In no one of the changes in the three forms of matter—solid, liquid and gaseous—is there so

much heat taken up as in the change from a liquid to a gaseous (or vaporous) form, and in no other body or substance is so much heat absorbed or become latent as in the formation of steam from water, or in other words, in the process of evaporation; and the quantity of heat taken up by the moisture which a dry air abstracts from the skin is so great, that the mere differences of temperature of the air, from that of the skin, may almost be neglected in the statement: and it is very nearly correct to assert that the cool sensation from a breeze in summer, proceeds entirely from the evaporation of moisture thereby induced.

Upon this basis it may be noticed that a current of saturated air at 100° would neither remove heat by its contact nor by induced evaporation, and consequently would be incapable of producing a cooling effect, while as the temperature or the dew point should fall, the current would become a pleasant one. With a high temperature and dry air, the cooling effect of a current of air (even at 100°) may be very pleasant in the sensation, but will be attended with sun-burning (even without exposure to the sun), and blisters will be produced by the excessive deprivation of moisture from the cuticle or surface of the skin. With 80° of temperature and a high dew point, a strong breeze is not unpleasant, nor likely to be injurious after the person shall have acquired some *accustomed* habit of body to endure it; but at 70° and a low dew point, which is the only possible condition of heated air in mid-winter, the annoyance of a current of even five feet per second and its unhealthiness are positive facts.

§ There remain to be considered two more relations of moisture in air, to health and comfort. First, the effect of evaporation of water by the air itself in summer, in reducing the temperature to one of comfort; and secondly, the effect on the moisture condition of the air of summer, when it is attempted to cool air by artificial means.

The cooling of air, by spontaneous evaporation from extended surfaces, is of frequent practice in hot countries by the wealthy inhabitants near the banks of rivers where the water supply is abundant. The condition of the air which makes it practicable is one of great heat, and of a relatively low dew point; and the summers of Egypt and of parts of India, especially of Bengal, give opportunity to employ this method of cooling air. If it is accepted that the temperature of the air in the shade, in the localities referred to, will sometimes run from 85° to 105° for many consecutive hours, accom-

panied with, say, 50 per cent. of moisture for the 85° of temperature, or, say, 30 per cent. for the 105°, then the evaporation of moisture from wet surface can be relied upon to produce a comparatively comfortable atmosphere. Air at 85°, with 50 per cent. of moisture, has quite exactly the same quantity of moisture, per given volume of air, as that at 70° and 70 per cent. of moisture. So that if it could be cooled *without* adding moisture at all, it would then reach the point of comfort for the clothed inhabitant of the temperate zone. If the dew point of 85° is brought up to 80 per cent. or above, the air becomes intolerably sultry, and at 90 per cent., quite suffocating; so that the greatest addition of moisture practicable to the supposed air of 85° and 50 per cent. dew point, may be taken as 10 per cent., or 1¼ grains to the cubic foot. The resulting figures which the latent heat demanded for the evaporation of these 1¼ grains of moisture into the air supposed, is 74½°, and 82 per cent. of humidity. How far this condition of the air may be more comfortable than the original one of 85° and 50 per cent. of humidity, is questionable; but it is apparent that the limit of possible cooling of air of 85°, by evaporation of moisture, is found when its humidity is not to exceed 50 per cent. of saturation. A similar computation applied to air of 105° (in which air there is a little more moisture than in that supposed at 85°) gives, for the addition of 1¼ grains of moisture to the cubic foot, air of 94½° temperature and 48 per cent. of humidity—an atmosphere which *may* be, in some degree, more comfortable to a person at rest than the normal one. It is evident, that for efficiency in cooling air of 105° by evaporation from moistened surfaces, the humidity of the air to be cooled should be less than 30 per cent. As to ultimate healthfulness of the moistened air, it *seems* to be unquestionable that the supply of moisture ought to promote disease.

We have, however, in each year in our country, a few days or parts of days (perhaps, in the Southern Middle states, ten to twenty days in different years), when the range of thermometer and the dew point make it feasible to adopt this means of reducing the apparent heat of the air. The attempt has been frequently made, with provoking failure to the projectors. Its success depends upon not only the exact condition of relative humidity and temperature, but also on the proportion of surface of evaporation to the quantity of air to be supplied. The Indian ratio is one or two persons to six to eight square yards of wet surface. But the most provoking cause of

failure has been, that while there are ten to twenty hot dry days in any year, there are also twenty to thirty hot damp ones, and the application of the *cooling* apparel to the hot air on these days, has produced such an effect of sultriness that the whole has met with instant condemnation.

The last relation of moisture to air to be considered at this time is that which proceeds from the effort to cool air artificially. The fallacies of the attempts to effect this purpose can be made very apparent. Even the smallest decrement of heat is obtained only at great cost. The *quantity* of cooling of air in summer is, to be sure, only about one-fourth that of heating in winter. Taking the ideal temperature of 70°, there may be 15° to come off in summer as generally as 60° to be added in winter, and supposing iced water to be the cooling medium, and steam of low pressure to be the heating one, the relation of difference of temperature of the air to be cooled or heated to that of the iced water or steam, is such, that about the same extent of surface would be required in either case to transfer the heat. But a pound of coal produces, in ordinary steam boilers, quite 9000 units of heat on the average, while a pound of ice (in cooling to 60°, let us say) will produce only 170°, so that about 54 pounds of ice would be demanded to effect the transfer of an equal quantity of heat, to what would be effected by 1 pound of coal; or, accepting the one-fourth cooling effect, then 13½ pounds of ice would be demanded for the cooling of air in summer against each pound of coal required for warming in winter. Unfortunately for the proposition for cooling *air* in summer, even this statement is too favorable, for the requirement will be found that the air must not only be cooled, but must be divested of a portion of its moisture, unless the cooled air is deemed satisfactory in the form of a cloud of vapor. Air at 85° and 70 per cent. of humidity must be taken to be cooled to 70° and 70 per cent. of humidity, and one and one-fourth times as much cold will be demanded to condense the vapor 2·3 grains per cubic foot, as that which is requisite to cool the air the 15° supposed. This leaves the ratio of ice needed to obtain a spring condition for the air on a hot day in summer, to be that of 30 to 1 of coal usually demanded to heat air on a cold day in winter, or assuming that the air on such a day is so dry that no moisture should be removed, about 15 to 1. Our ideas of the necessities of civilized wants, as compared with civilized luxuries,

scarcely yet reach high enough to warrant the expenditure of money to cool air under the circumstances stated.

In view of the great cost of cooling air by ice, it has been proposed to cool it by mechanical means on a large scale. Air, if compressed, becomes sensibly hotter. The compression can be carried to the extent that the heat will ignite tinder, as the cigar lighters of twenty or thirty years since bear witness. And it has been proposed to use large air pumps which shall compress the air until its temperature is elevated sufficiently for it to give off heat to surfaces cooled by currents of water, at such temperature as water is to be had from streams or aqueducts in summer. This compressed air, when deprived of a portion of its heat, is then allowed to expand, and the result is a cooler air. This process really has considerable merit, and it is probable that the cost of producing cold in this way, compares favorably with the use of ice; in fact it has been shown that ice itself may be manufactured with profit by this process in some localities, where transportation enhances the price of ice largely. But it is preposterously expensive for apparatus and cost of working as a means of cooling air in the great quantities demanded for ventilation, and the humidity of the cooled air will still be objectionable. The comparatively high temperature of the surface for cooling the air will fail to be very efficient in condensing the vapor thoroughly. In both the methods of cooling air, whether by ice or by water (of which great quantities would be needed), the cooling surface must be copper, brass or tin, as the rusting of iron, when exposed to condensing vapor, is extremely rapid.

The most probable result of cooled air would be a thunder-cloud in miniature. The atmosphere on one of our hottest and most sultry days of summer is on the verge of a tempest. Cooling of air of 85° to 90°, to the extent of 20° or 30°, produces a dense mist of supersaturated cooled air. The equilibrium of the atmosphere on a still, clear summer day, when every growing thing on the surface of the ground is supplying moisture, and the radiation of the ground itself is supplying heat to increase the relative levity of the strata of air next the ground—the equilibrium of such an atmosphere is very unstable. Let an upward flow be established anywhere, and the air will rush in all directions along the surface to supply the partial vacuum. The ascending column, as it reaches the region of lower barometrical pressure, will expand, become sensibly cooler, and in a short five to

eight miles of height, the region of frost and ice will be reached, and hail-stones will be returned from the condensation of the transparent vapor which had existed in the air when it left the surface of the ground. The writer once saw in a little ball-room, on a Christmas Eve, a miniature snow-storm deposit a little bank of snow, from the opening of windows to air the room, when the dancers had retired; the night being a clear moonlight one, with the thermometer a little above zero.

The difficulty of absence of moisture in air that is heated in winter is a matter to be disposed of with some happiness, by asserting that moisture is not wanted, and in summer the objection of presence of moisture in cooled air can be only overcome by not cooling the air. It does not seem that the successful cooling of our summer air, so as to produce a comfortable or healthful condition at spring temperatures, has any probability of accomplishment.

Quoting as an appropriate final remark the words with which I concluded another paper having an especial application to a system of ventilation: "I will not follow further the proposition to change the seasons into a perpetual springtime—practical ventilation is the supply in dwellings, of an abundance of fresh air at the several seasons, warmed to the temperature of comfort in winter, and supplied in quantity to the volume of comfort (as near as possible of the quality and condition of out of doors in the shade) in summer. The truth is, all our heating and ventilating appliances are the compromise of condition—a truth extending beyond all mechanical operations to the phenomena of nature itself."

NOTE REFERRING TO ARGUMENT IN THIS PAPER, AS RELATED TO ENGLISH EXPERIENCE.—The following quotation from a recent English writer, will convey some idea of the effect of the supersaturated atmosphere of a London fog: "There can have been but few people in London last November (1873), who did not, during the heavy fogs, experience some difficulty in breathing—in getting a sufficient supply of oxygen for the lungs, to carry on the vital processes in the usual manner. On one of the last days of its duration, many people one met in the streets seemed to find breathing painful; they were apparently now and then gasping for breath, and the thought occurred that it was by no means impossible, by a continuance of such weather, for a whole cityful of people to be suffocated. The mortality amongst the sick was very great, and the state of the air caused the death of many prize fed beasts sent to the cattle show at the agricultural hall, at Islington. It would be wrong to suppose that the air was impoverished of oxygen to such extent as to cause asphyxia, but a serious amount of inflammation, and, perhaps, a partial obstruction of the air passages of the lungs, was caused by the inhalation of soot, tarry matter and chilly particles of water."—"*Air and its relations to Life*," Dr. Walter Noel Hartley, London, 1876. 2d edition.

THE HAYFORD PROCESS AND APPARATUS FOR PRESERVING TIMBER.

By Edward R. Andrews, of Boston.[1]

[Continued from Vol. lxxv, page 118.]

Value of Process.

Now let us retrace our steps, and see whether, practically as well as theoretically, the advantages claimed for the Hayford patents have been realized.

I have shown you that to preserve wood from decay, it must be placed in the following conditions:

1. It must be rendered non-fermentable by the coagulation of the albumen of the sap.

2. *Dryness* must be secured by the abstraction of the sap and moisture contained in it, as well as any sugar or acids, which would have a tendency to ferment.

3. *Dryness* and a pure woody fibre being secured, these conditions must be maintained by protecting the wood in some way from air and water afterwards.

In reply, I claim: First, that inasmuch as albumen coagulates at 140°, and that all the sap containing albumen is to be found in the sap-wood, and that it has been steamed to 240° or 270° Fahr., the albumen has thus been rendered non-fermentable. Moreover, creosote oil contains the most powerful coagulator of albumen known to science—carbolic acid; hence, when injected into the pores of wood, it doubly secures it from fermentation.

Secondly. By the action of the steam heat, and the subsequent use of the vacuum pump, the sap and water held in the wood have been vaporized and withdrawn from the pores of the wood, leaving a pure woody fibre. Nothing liable to ferment remains in the wood.

(This system of drying lumber can be made very valuable for carpenters. In twenty-four hours green lumber can be seasoned more completely than in an ordinary dry-house in six weeks. For this purpose the drying process should be continued for some time after the vacuum has been reached, the heat being kept up by the radiating coil of pipe.)

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[1] Paper read before the Franklin Institute, January 16th, 1878.

Thirdly. Freedom from liability to fermentation and dryness being secured by the earlier processes, the wood is made water-proof and air-tight by injecting the pores with creosote oil.

Creosote oils are also called dead oils, or the heavy oils of tar. They contain from 5 per cent. to 15 per cent. of carbolic acid, and several other highly antiseptic and preservative constituents, besides paraffine, naphthaline, etc., which all play their parts in the preservative processes. Heavy oils are produced in the distillation of crude coal tar, as it comes from the gas houses. They come off after the light and volatile aniline oils, say at a temperature of 300° to 600°. The residuum is pitch.

Creosote oil, forced into the pores of wood at a high temperature, being far more penetrating than any other oil, works its way through the pores until it covers every fibre with a protecting film. It resinifies in the outer pores, and, impacting there, keeps the main body of oil within, and, being insoluble in water, it forms a water-proof and air-tight covering to the wood, and maintains absolute *dryness*. No matter where the wood may be exposed, it is protected from absorbing any fermentable substance. Hence, decay is rendered almost impossible.

The preservative qualities of the heavy oils of tar are not due, solely or chiefly, to one or more of its component parts, although several are esteemed highly as preservative substances; but their efficacy is due, chiefly, to the thick, greenish oil itself, which is *insoluble*. It is this quality, *insolubility*, which gives to the heavy oils of tar their superiority, as preservatives, over chloride of zinc, sulphate of copper, or corrosive sublimate. These latter only coagulate the albumen, they offer no protection whatever to the wood itself; the woody fibres are as much exposed as ever to absorb destructive agents. But when wood has been injected with creosote oil, which works insidiously through its fibres, not only is the albumen coagulated, but the whole structure is so absolutely preserved and protected, that its indestructibility is assured, except from actual wear. It is benefited on this score, also, as it becomes harder by time. Creosoted wood is the only wood which seems to improve with age. The oil seems to metalize the fibre like iron. Soft wood becomes hard, like oak. Sap wood becomes as hard and durable as the heart-wood.

In the early part of my remarks I stated that the Hayford patents, for preserving wood, covered a system which is adapted to the wants

of this country. This is mainly, as you have observed, because it is able to cope with green lumber. It can receive it from the saw-mill, and in 24 hours thoroughly season and preserve it. In fact, to do good work it is essential to have green wood. It is precisely in this condition that wood will readily absorb creosote oil, when the moisture has been withdrawn. In a living tree, the fibres and pores of wood are not hard and flinty, like those of kiln-dried or air-seasoned lumber, but are soft and porous. The cells act as so many millions of pumps, to transmit the sap from the roots to the leaves and return it again to form the annual layer of wood growth. When the sap has been withdrawn from wood in this condition, as has been described, without hardening the fibres, the cells and fibres are just as ready to receive or transmit creosote oil as sap itself.

Creosoted Wood will not Decay.

I have assumed that you are all familiar with the fact that wood thoroughly creosoted will not decay. This is a fact, proved by the accumulated evidence of 40 years in England. Creosoted wood has never been known to decay. Engineers in this country need not wait a generation to learn that this is so. It was accepted as proved in England 30 years ago, and in engineering works the strongest testimonials of the value of creosote oil, as a preservative against decay, are recorded by all the great constructive engineers in Europe.

There is scarcely a railway in England which does not use creosoted ties, bridge timbers and platforms, and the same roads use them to-day which began their use in 1840. The Belgian system of railways, which is under government management, uses creosoted ties solely, and the same is true of all the railways of Northern Europe.

Some engineers here have told me that ties wear out before they rot. That may be true in some cases; but I ask, if creosoted ties do not wear out in 20 years on the great roads in England, why should they wear out here? It is a remarkable fact that it is difficult to find any old ties in England for specimens of creosoted work. These specimens from the Great Northern Railway of England, which have been in wear from 10 to 14 years, were actually taken out of the road-bed to be sent to me. No piles of old ties lying by the side of the tracks, only fit for fuel, are to be seen in Europe as in this country.

My belief is, ties begin to decay before they begin to wear out. As a rule, ties are half buried in the ground in a green state, full of

sap in a fermenting condition. Wet rot sets in at once, favored by the exposure to alternate dryness and moisture, particularly under the rail, where the surface begins to decay at once, hastened by the rust from the rail; at the same time the spike driven into the moist wood begins to corrode; water works down by the side of the spike, the spike loosens and plays, and then comes the trip-hammer action of the rail every time a train passes over it. It is no wonder the tie cuts and is thrown out, often within the first year.

But with a creosoted tie the spike will not corrode and will not work loose; the surface of the tie under the rail will not decay or wear, because not affected by alternate dryness and moisture; there will be no play of the rail upon the tie, and consequently no friction and no cutting. No, there is every reason for believing that creosoted ties will last here 20 years as well as in England, and their general use would be equal to a saving of 3 per cent., per annum, on the cost of the railways of this country.

I have referred principally to the uses of creosoted wood on railways, because they are the great consumers of lumber, but it should commend itself equally to architects, builders and carpenters.

Creosote as a Protection against the Teredo, etc.

I have referred thus far to creosoting as a protection against decay only, but it is equally a specific against destruction of wood by marine worms. This quality of dead oils is almost as important as their efficacy against decay. Bear in mind that from Maine to Texas there is scarcely a point on our coast, where our piers and wharves are not rapidly destroyed by the Teredo Navalis, or the Lymnoria Terebrans.

On the table before me are specimens of wood destroyed by these ravagers at different points, in a few months or years, at Boston, Provincetown, New York, and the Gulf of Mexico.

So far as I am aware, the teredo is not found north of Cape Cod, but the lymnoria is scarcely less destructive.

In many places in the Gulf, the teredo will destroy large piles in a single year. They are found sometimes two feet long.

The teredo infests the coasts of Great Britain, Holland, Belgium and France, and is quite as destructive there as here; were it not for the use of creosoted piling, the piers of their harbors would require to be rebuilt every three or four years. There is not an

instance on record where a pile, impregnated with creosote, to the extent of 10 or 12 pounds to the cubic foot, has been approached by the teredo or the lymnoria. Piers built in 1850 are perfectly sound to-day.

Places where Creosoted Wood has been used as a Protection against the Teredo, in Great Britain.	Dates.		Duration.
	When exposed.	When last examined.	
Port of Sunderland, . . .	1839	1859	20 years.
" Teignmouth, . . .	1842	1849	7 "
" Lowestoft, . . .	1846	1859	13 "
" Leith, . . .	1848	1862	14 "
	1854		8 "
" Southampton, . . .	1848	1852	4 "
" Brighton, . . .	1848	1851	3 "
" Manchester, . . .	1850	1861	11 "
" Portland, . . .	1853	1861	8 "
" Holyhead, . . .	1854	1861	7 "

The importance of protecting these harbor works has been considered so serious a matter, that most careful experiments have been tried, extending through a series of years, under commissioners appointed by the different governments, whose official reports are accessible to all. Every other suggested remedy was tried, and failed in every instance. The terrible mollusk or crustacean seemed to fatten upon every poison, and would manage to work its way between copper- or iron-headed nails or copper plates, but he turned his back invariably upon creosote.[1] All the official reports agree upon this point, that creosote, and that alone, thoroughly injected into wood, will protect it completely.

There is, however, one other remedy, and that is sewerage. It is fortunate that sewerage serves one good purpose. These enemies require clear, salt water, free from any brackishness. It carefully avoids a pier in New York, where a sewer empties, but it luxuriates in the next, which is free from that nuisance.

[1] See papers by E. H. Von Baumhauer, on "The Teredo, and the means of preserving wood from its ravages;" Archives of Holland, Vol. I, 1864. Auguste Forrestier, Engineer of Roads and Bridges; Annales Françaises, 1864. M. Crepin, Engineer of Roads and Bridges of Belgium; Report of experiments at Liege, from 1857 to 1867.

The importance of creosoting ship timber should not be overlooked. I have specimens of birch before me taken from the side of a vessel, which had been six months at Key West, completely riddled by the teredo. How often may it be that vessels, lost at sea and never heard from, have sprung a leak through some teredo eaten timbers. Remember, too, that dry rot would be prevented also, and, perhaps, all necessity for copper bottoms. It would seem that creosote is as useful at sea as on land. Its use is everywhere a true economy.

Our own Government has the honor of being the first to creosote ship timbers. In 1872 creosoting works were erected at the navy-yard in Charlestown, under the superintendence of Mr. Hayford, who took charge of the treatment of the timbers for the "Vandalia," the vessel which is now the home of Gen. Grant, in the Mediterranean.

The ribs of the "Vandalia" are of live oak, but all the rest of the planking and decks, inside and out, were creosoted by Mr. Hayford. This vessel was completed in 1873, and fitted for sea in 1875. Thus far no report has been made of her condition to the Department.

It is well to select, for creosoting, woods which are porous and will absorb oil readily. Cheap woods, which, unpreserved, rot quickly, can thus be made more solid and more enduring than the most expensive timber. I think the cotton wood of the Southwest can be made as useful as oak for ties. White pine absorbs creosote like a sponge, and the yellow pine of the South takes it readily also. In England, fir from the Baltic is used altogether for ties, and I do not see why the despised fir from our forests may not be used for the same purpose here. Hemlock is good also; it holds a spike well. Spruce is a firm, compact wood, and absorbs oil with more difficulty, neither does it require so much to preserve it. Its sap-wood, where decay commences, is always saturated, and the heart, if treated green, shows more or less oil all through the annular rings. Oak has a coarse fibre, and is easily treated.

The limits of a single evening are insufficient, Mr. President and gentlemen, to do justice to so important an industry as this. I thank you for your kind attention, and need not say that I shall be glad, as far as I can, to answer any questions which may lead to a clear and full understanding of a subject in which so many of you, I am sure, must feel a deep interest.

The speaker presented, in support of his views and statements, a large number of letters from engineers in this and other countries, referring to some important works where creosoted timber had been exposed for many years, with the most satisfactory results: among which are the Yorkshire and Lancashire Railway, England, Southern Railroad, France, the Leith Pier, Edinburgh, Scotland.

Among the letters is the following, referring to the

WEARING OF RAILROAD TIES.

"*Boston, Feb. 6th*, 1878.

"EDWARD R. ANDREWS, ESQ.,

"*Dear Sir:*—In answer to your enquiry, I will repeat what I said at a recent meeting of the Boston Society of Civil Engineers, on the subject of treated and untreated railroad ties. I have been of the opinion for some ten or twelve years, that the frequent remark that 'railroad ties will wear out (*i. e.*, cut through) before they will rot out,' is an incomplete and misleading statement, as it is usually made. It supposes that treated (creosoted, kyanized, Burnettized, etc.) railroad ties will wear and cut the same as untreated ones; whereas the *fact* is, as shown by the records of foreign railroads, beyond dispute, that treated ties *wear* longer, do not *cut through* so quickly, and hold the spike longer than untreated ties. I have my own explanation of this fact, but whether the same is correct or not, is really a matter of no especial importance. What we are after are the facts. Still, I will give the explanation that I have arrived at for my own satisfaction, submitting the same to criticism. It is that, after all, what we call 'cutting through,' 'wearing out,' 'refusing to hold the spike,' etc., in railroad ties, is nothing more or less than rotting, with this single distinction, that it is a local rotting, a decay in certain spots and places only, and not that of the whole body of the tie; and that, therefore, a treated tie, which resists decay better, any and everywhere, within it and on its surface, will wear longer, cut less, and hold the spike longer.

"The first time I had occasion to reason in this manner, was in observing the dropping down into the ties of the cast-iron chairs of a piece of 'English' double-headed rail track on the Boston and Albany R. R. The chairs were frequently an inch and an inch and a half imbedded in the tie, and the cup so formed was filled with water after every slight rain or heavy dew, and it seemed to me plain that this concentrated wetting and drying in that spot could not fail to rot the tie faster right under the chair than elsewhere; and adding that to the pounding action of the traffic over the road in the same spot, it made clear to me why the tie wore out before it rotted out, and at the same time satisfying me that a 'properly treated tie' would behave better under the same circumstances.

"Respectfully yours,

"CLEMENS HERSCHELL,

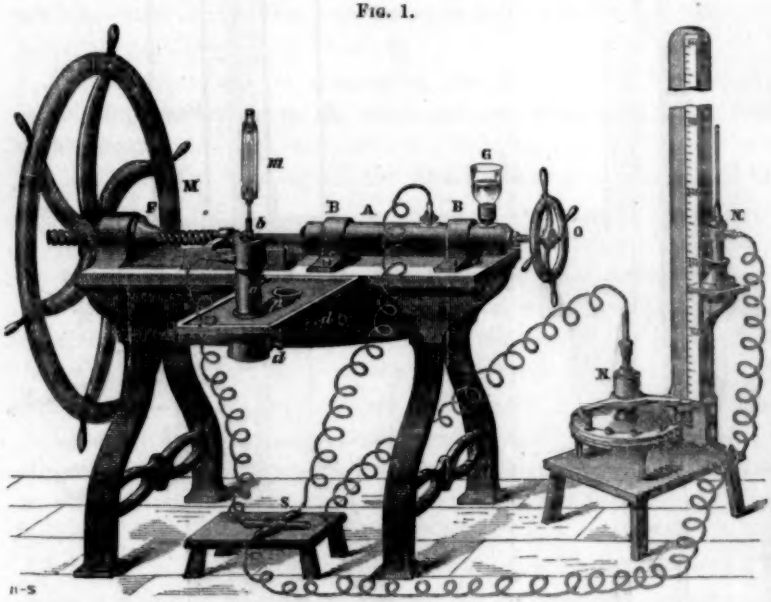
"*Civil and Hydraulic Engineer.*"

M. CAILLETET'S APPARATUS FOR LIQUEFYING GASES.

In the last number of the JOURNAL were given illustrations of the apparatus employed by M. Pictet for liquefying gases, and a brief description of that employed by M. Cailletet for the same purpose, and we are now able to give illustrations of the latter.

In Fig. 1, *A* is a hollow steel cylinder, bolted down by means of the straps, *B*, *B*, to the bed of the framing which supports the apparatus. Entering this cylinder is a steel plunger, having cut on its outer end a square-threaded screw working in the nut, which

FIG. 1.



forms the hub of the large hand-wheel, *M*. The nut is supported by, and revolves in, the strong journal-box, *F*, in such a manner, that the plunger will be advanced and retreated according to the direction the large hand-wheel, *M*, is rotated. The cylinder, *A*, being filled with water, a very high pressure may be produced in any vessel to which it may be connected, upon turning the large hand-wheel. A leather cupped packing prevents the escape of water around the plunger.

The cylinder, *A*, is filled with water through a passage at the bottom of the cup, *G*, which passage is controlled by a conical pointed screw-plug, operated by the small hand-wheel, *O*, as shown. This opening is also employed to relieve the pressure brought to bear on the gases experimented on, allowing their sudden expansion. At-

FIG. 2.

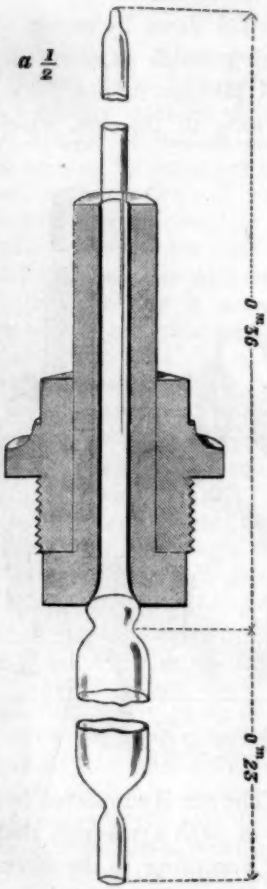
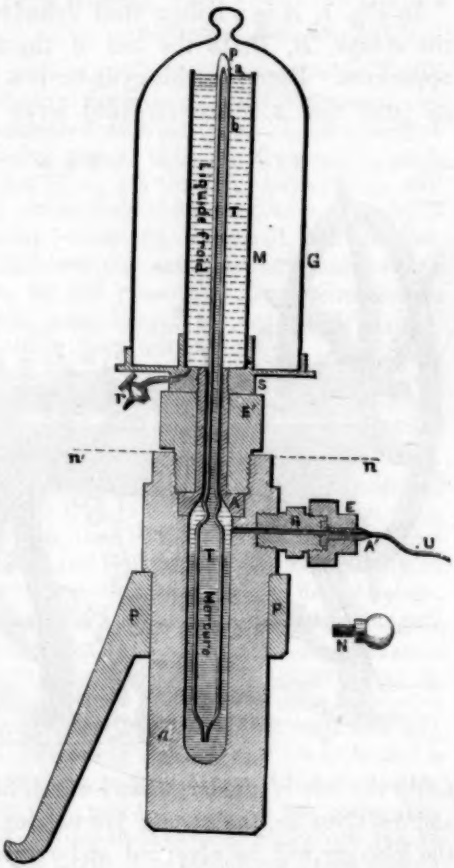


FIG. 3.



tached to, and supported by, the tablet, *p*, is the hollow cylinder, *a*, capable of sustaining a pressure of 900 to 1000 atmospheres, and is connected to the compression cylinder, *A*, by a small metallic tube. The lower and enlarged end of the glass tube, containing the gas to be experimented on, is inserted into the reservoir, *a*, and held in

position by the hollow plug at *b*, as shown in Fig. 2, which is half size.

Fig. 3 represents all this portion of the apparatus in section, supported on a simple tripod, *P*, for use in lecture experiments, in connection with any powerful force pump. Surrounding, and concentric with, the upper end of the tube, *T*, *T*, is placed the cylinder, *m*, which is filled with liquid nitrous oxide, or other freezing mixture. The exterior envelope, *G* (not shown in Fig. 1), contains material to absorb the moisture, which would otherwise collect on the glass cylinder, *m*, and obstruct observation.

N and *N'* are gauges for determining the pressure employed, and are connected to the other portions of the apparatus by small metallic tubes, through the branch piece, *S*.

E is a hollow nut for connecting the pipe, *U*, and *N* is a plug for closing the orifice in *R*, when the reservoir, *a*, is being filled with mercury.

e is a cock for drawing off the liquid freezing mixture from the glass envelope, *m*.

The tube, *T*, *T*, while open at both ends, is filled with the gas to be experimented on, and the upper end, *p*, is hermetically sealed. The other end being closed with the finger, it is introduced into the receiver, *a*, in an upright position, and the mercury, with which the latter had previously been nearly filled, enters the lower end. The other parts of the apparatus are then placed in position, as shown.

Upon turning the large hand-wheel, *M*, Fig. 1, in the proper direction, the water from the cylinder, *A*, is driven into the receiver, *a*, through the tube, *U*, Fig. 3, and pressing upon the surface of the mercury, forces it into the tube, *T*, *T*, reducing the space occupied by the gas in its upper end. After this operation has proceeded for a few minutes, a mist of compressed gas is produced, which finally collects, in a small liquid mass, at *b*. The large end of the glass tube, *T*, *T*, is subjected to the same external and internal pressures, and, therefore, is not liable to break. The upper portion, having a very small bore and thick walls, is sufficiently strong to support the pressure, and should it be ruptured, no serious consequences could result.

The apparatus is easily managed, and with it, and the aid of the oxy-hydrogen light, all the phenomena of the liquefaction of gases can be projected on the screen.

DENSITY OF LIQUID OXYGEN.[1]

By M. Raoul Pictet.

"You arrive at the expression of the density of liquid oxygen as being represented by $\frac{16}{16} = 1 = \delta$ in the solid state, and probably the liquid one also, neglecting the variation due to expansion.

"I have the great satisfaction of being able to announce to you the complete experimental demonstration of the theoretical views enunciated by you now some time ago at Geneva. This demonstration has been arrived at as follows:—

"I know directly and very exactly—

"I. The exact volume of the interior of the wrought iron shell and the volume of potassic chlorate decomposed into oxygen and potassic chloride.

"II. The temperature of the shell at the moment of complete decomposition.

"III. The volume of the tube in which the condensation of oxygen is brought about.

"IV. The pressure before and after condensation.

"V. The pressures indicated by the manometer after two or three successive jets, till the moment the point of saturation is reached, and after which the gas issues in a gaseous form.

"These various data, combined with the gaseous density pressure and temperature, lead me to the conclusion that a difference of 74·26 atmospheres on the manometer represents the variation of pressure corresponding to the condensation of oxygen in the tube immersed in the carbonic acid.

"This variation has been exactly observed in the last three experiments which I have made with the assistance of many of my colleagues here at Geneva.

"The quantity of liquid oxygen which we had in the tube was 45·467 grammes, corresponding to a volume of 46·25 cubic centimetres. But it is possible that the highest part of the thin tube had

[1] Letter to M. Dumas. *Comptes Rendus*, Jan. 7th, 1878.

some centimetres in length not occupied by the liquid. This may explain the difference of 0·8 gramme found.

"Moreover, very volatile liquids have such considerable expansions that it is indispensable to have exactly the temperature to which they are subjected, in order to determine their true density. However this may be, there is an absolute verification, within small limits, of error of the theoretical calculation regarding this physical constant."

In addition to this important result, in another experiment, M. Pictet has used polarized light to determine the presence or absence of solid particles of oxygen in the jet. The jet was illuminated by means of the electric light, and observed with two Nicol prisms. A very strong polarization was observed, indicating the presence of solid particles, which in all probability were really solid particles of oxygen.

LIQUEFACTION OF HYDROGEN.[1]

By M. Raoul Pictet.

"*Geneva*, January 11th.

"I have the pleasure of giving you the result of an experiment carried out by me on the evening of Thursday, the 9th inst., with a view to liquefy and solidify hydrogen.

"This apparatus was exactly the same as that for the liquefaction of oxygen. I made use of nitrous oxide instead of carbonic acid.

"To obtain hydrogen under pressure, I decomposed formiate of potash with caustic potash. The hydrogen is given off without a trace of water, and the residuum is not volatile, two conditions essential to obtaining exact observations. The reaction has a well-defined temperature, above which it did not rise, the hydrogen being given off with perfect regularity, at a rate corresponding to 252 litres at zero. The pressure rose to 650 atmospheres before it stood still. The cold was about — 140° (I have not yet reduced the measurement of the temperature). On opening the stop-cock, the liquid hydrogen issued with vehemence from the orifice, making a piercing, whistling sound. The jet was of a steel-blue color, and was com-

[1] Letter to M. Dumas. *Comptes Rendus*, Jan. 14th, 1878.

pletely opaque for a length of about 12 centimetres. At the same moment a sharp rattle was heard, similar to the sound made by falling gravel, and the whistling sound was changed into a peculiar hissing, resembling the noise made by a fragment of sodium when thrown on water. At almost the same moment the jet became intermittent, each pulsation of it being felt in the tap.

"During this first outrush of the hydrogen, the pressure receded from 650 to 370 atmospheres. On closing the tap, the pressure gradually fell for several minutes, reaching 215 atmospheres, from which it rose slowly to 225, where it remained stationary a second time. I opened the tap again, but the jet was so intermittent in its motion that it was evident the congelation of the hydrogen had been effected in the tube. This supposition, on my stopping the pumps and the freezing, was proved to be correct by the gradual outflow of all the hydrogen. The difference between these results and those I obtained for oxygen, I explain in the following way:

"Hydrogen has an atomic weight sixteen times less that of oxygen; the latent heat of hydrogen ought, therefore, to be ten times above that of oxygen. As soon as the outflow tap is opened, the liquid collected in the tube evaporates in part, absorbing so much heat in the change of state, that the remainder solidifies in the tube before being expelled.

"For more than a quarter of an hour we had successive discharges of hydrogen from the orifice of the tube. The mist produced by the expansion of the gases at the commencement of the experiment fell as low as the ground, ceasing completely as soon as the jet became intermittent, the phenomena corresponding to the congelation of the hydrogen in the interior of the tube.

"It is impossible to confound the vesicular mist of the gas with the appearance of the liquid jet seen at the beginning of the experiment. These various appearances are clearly distinguishable, and give rise to no sort of ambiguity. I know the volume of the residuum, and in a future experiment shall be able to determine the density of liquid hydrogen."

WATER SUPPLY OF THE STATE OF NEW JERSEY.

Report by the Committee on Water Supply, read at Meeting of New Jersey State Sanitary Association, held at Princeton, Oct. 17th, 1877.

By ALBERT R. LEEDS, Chairman.

We shall endeavor, as was done in report of last year,[1] to lay down certain general principles affecting the whole question of water supply. In the first place, it will be seen by an examination of the physical features of the state, that it is naturally divided up into a limited number of great hydrographical basins. By hydrographical basin we mean all that area, the rainfall of which finds its way down to the lowest level, by a connected system of greater and less tributaries, into one main water-course. Such, for example, is the Hackensack basin, the water-shed of which, including Rockland Lake, is 84 square miles, or together with Closter Brook, about 16 square miles, amounts in all to 100 square miles. The Passaic basin, which, including that of the Ramapo, 148, the Ringwood, 108, the Rockaway, 165 square miles, and other streams of less magnitude, amounts in all to 750 square miles. If we assume that the least annual rainfall is 30 inches, the entire bulk of water drained off the Passaic basin would amount to about 390 billions of gallons annually, or something more than one billion per diem. The drainage of the Hackensack basin is 52 billions of gallons annually. Similar remarks and calculations would apply to the Raritan and other basins, but are omitted from lack of immediate practical importance.

In the second place, it is a well-recognized law, that commodities attain their greatest value for purposes of exchange, when they arrive at the lowest practical point above sea-level, and hence great commercial centres are generally built up at the lowest points of such hydrographical basins, and usually at or near the mouth of their main water-course. In the early history of these commercial ports, the great river on which they are located brings them not only agriculture and trade, but also an apparently inexhaustible supply of pure drinking-water. At this period of development, their water-works are placed a few miles up the river beyond the town, and we notice as the first phase of the water supply system, Newark and Jersey City

[1] See "Recent Progress of Sanitary Science," *Amer. Chemist*, 1877.

pumping their supply from the Passaic, New Brunswick from the Raritan, Philadelphia and Camden from the Delaware, and so on.

In the third place, the development of agriculture and commerce is quickly followed by manufacturing industries, and every adequate waterfall in the hydrographical basin is seized upon for power; in the beginning, to turn the forests into timber; and, when the woods have been recklessly cut away, to grind grain, card and weave woolen fabrics, and, with increasing wealth, supply paper-mills and dye-works, bleacheries, silk-factories, all varieties of metal and chemical works, manufactories without number and of endless varieties, each sending downward its own burden of refuse—greater or smaller in amount, less or more pernicious. Exactly the nature and amount of this refuse, can be best learned from the elaborate statistics compiled by Mr. L. B. Ward, and published in the Seventh Annual Report of the State Board of Health of Massachusetts. A deliberate examination of Mr. Ward's figures teaches more forcibly than words, however strong, to what death-dealing consequences that pollution has now attained in some of the manufacturing streams in Great Britain, and may be expected to reach in this country, with the growth of our manufactures and the lack of repressive legislation. Neither could we do aught than injustice to a statement, itself condensed from the great mass of English reports, by attempting to epitomize it here. But, when we consider that in the manufacture of wool into fine cloth it passes through upwards of forty steps, in ten of which water is used, and greatly fouled almost as often as used, and that five parts in one hundred of the waste liquids are impurities, and of these, three parts are putrescible nitrogenous matters, we can form some faint conception of the pollution from this source alone. If we add to this, the vegetable dye-stuffs and the animal excrements, the acids and alkalies, the metallic salts—including even those of arsenic, employed in cotton manufacture—and, furthermore, the compounds of chlorine and sulphur, used in bleacheries, the rapidly decomposing waste products of tanneries, paper-mills, sugar-houses, starch-factories, and liquor-distilleries, we appreciate the magnitude of the polluting agencies which have long since killed all fish life in many European streams, and turned some into sewers, rolling down toward the sea a pestilential flood of foul-smelling liquids black as ink.

Moreover, there exists, along our Atlantic seaboard, a peculiar physical cause for the building of a large manufacturing town upon

the main water-courses, at a point somewhat above that at which the tidal city is located: the abrupt plunge from the hill country forming the upper portions of the hydrographical basin, down to the level of the alluvial or other recent formation lying along the sea-coast. Of this natural result, Paterson exhibits the most striking instance, and one which, at the same time, concerns us most nearly.

During all this period of transition, while the hydrographical basin is passing from an agricultural to a manufacturing territory, there are slowly growing up two quite antagonistic phases of popular opinion. The one, which is held mostly by dwellers in the hill country, by owners of mill sites and dam sites, by inhabitants of the water-power manufacturing towns, is that rivers were, to a large extent, beneficently designed to carry off sewage, filth of all kinds, and factory refuse. The other, which is in vogue among the greater number, those living near tide-level, is that rivers might, with greater fairness, be looked upon, not as sewers, but as gigantic aqueducts, designed by nature to supply, at small cost, dense centres of population with an adequate supply of pure drinking water. This latter might, for sake of distinction, be styled the "City of New Jersey" opinion; the former, at least until a considerable manufacturing industry shall have developed itself at Little Falls, or some upper point upon the Passaic, the "Paterson" opinion. The force of gravity is upon its side.

There is another cause, which tends to aggravate the hardships of those living near tide-water. It arises from the destruction of forests, and the rude disarrangement thus effected in the exquisite machinery of nature's physical laws.

When these rain detainers and precipitants are gone, the clouds hurry by without yielding up their needed stores of rain. The streams falling during summer-heats below their natural level, expose stretches of aquatic vegetation to poison with malaria, or engender confervoid growths which slay the fishy inhabitants, and taint the drinking-water with foul taste and odors. Or, if the rain clouds, encountering sudden cold blasts, suddenly discharge their contents, with no forest growth to detain them, and no undergrowth of sedge and moss for their absorption, they rush backward to the sea, tearing up in their course, and irrupting into the stream, decaying matters or filth accumulations, which, under happier circumstances,

would either not at all, or only by gradual steps, find their way into the great water-courses.

Thus many things conspire to make a deplorable result. The remedial agencies of aeration and oxidation, which, in the natural economy of flowing streams, nature has provided in amount more than adequate to dispose of all natural sources of fouling, now long since taxed to their utmost capacity by the growing load of sewage and refuse, in these seasons of drought or freshet prove inadequate.

The river now has its periodical sicknesses, and the population its periodical scares. The chemist is called in, and shows not that the water is bad, neither, exactly, that it is good, but only that it is not much better or worse than the water supply of some other city, which, like the Schuylkill at Philadelphia, and the Thames above London, has been used without the population falling ill of violent maladies. The chemist also reveals the surprising fact, that this same water, taken before the sewage was put into it, such, for instance, as the Passaic before it has left the hill country, is of remarkable purity, and nothing could be wiser or better than to get possession of this water before some other men have used it and passed it on. Then the engineer is summoned, and, after many more months, presents his array of figures, unhappily not in decimals, but in millions, showing how much it will cost to bring the water pure from its fountain head. At a total so appalling, the populace takes fright; the matter is dropped, only to be revived when the next sickness of the water supply excites an other newspaper scare.

This second period is the era of make-shifts in the water supply. It is rife in projects intended to increase the amount and improve the quality from tidal waters. To this class of make-shifts belongs that now before the public of constructing a dam across the Passaic River, at Belleville, to keep back the tide-water and sewage of Newark, with suitable locks to pass boats navigating the river at that point. The objection that the water would still be polluted by the sewage of Paterson and Passaic, is met by the proposed construction of an intercepting sewer, terminating below the proposed dam.

Another make-shift is the purchase of the Dundee dam, and the building of an aqueduct thence to the present pumping works. This plan would also necessitate an intercepting sewer from Paterson.

The last and final period is that which may be termed the era of ultimate water supply. This is reached when the great commercial

towns despair of redress in the matter of sewage. The time may come, and it is to be earnestly hoped it is not far distant, when the growth of enlightened opinion may induce communities to exert all possible means to dispose, as far as possible, of their own sewage without detriment to others, and, deficient though they may have been hitherto in point of pecuniary success, yet every help, that science or public co-operation can afford, should be extended to schemes of sewage utilization. But for the present, permanent results are looked for only in the direction of the ultimate water supply—that is, drawing it from the upper portion of the hydrographical basins, at levels higher than will be probably utilized for agriculture, or densely populated by manufacturing industries. Such an ultimate water supply is that of the upper Hackensack basin, favorably reported upon, after an extended investigation, by James P. Kirkwood, C. E., and, at time of present writing, favorably entertained by the North Hudson Co. Water Commission as the best available supply for Hoboken and adjacent towns. It provides for the storage of a supply of 30,000,000 gallons per day, a conduit capacity of 20,000,000 gallons per day, and a pumping capacity of 10,000,000 gallons per day, at an outlay of $2,832,070. If Jersey City delays much longer in making the imperative improvement and increase of the common supply, this Hackensack plan will probably be adopted. The more so, since in one year, that ending May 1st, 1873, Hoboken paid to Jersey City for its share $75,815, exclusive of cost for distributing pipes or interest thereon, while the annual cost to Jersey City was $175,000, thus affording the latter city a considerable profit.

The City of New Jersey, meaning by this name all that large population of which the cities of Newark and Jersey City are the crowded centres, has discussed and caused to be extensively examined very many plans of ultimate water supply. A most valuable presentation of this part of the subject will be found in the annual report of the State Geologist for the year 1876, in which the director of the State Geological Survey, Prof. George H. Cook, summarizes the chemical and medical, the topographical, meteorological and engineering knowledge pertinent to this question. He has also contributed very numerous results of analyses and surveys of streams and ponds throughout the Passaic basin, which have rendered that knowledge more precise on many important particulars. The most noteworthy of these plans of ultimate water supply are six in number:

1. *The Little Falls Plan.*—This proposes, in case the water-power at Little Falls can be purchased, to employ it in raising the water a height of 50 feet, and sending in through a tunnel in the mountain at Great Notch. It admits of the use of the whole water supply of the upper Passaic basin.

2. *The First Mountain Reservoir Plan.*—This has a like advantage. In raising the water from a point near Little Falls, it is proposed to use steam-power; in distributing it, the force of gravity is relied upon to supply all the towns between Orange Mountain and the Hudson River.

3. *The Rockaway Plan.*—This proposes to bring the water of the Rockaway from near Denville, mostly by natural channels, to near Morristown, thence by piping to the high ground back of Madison and Chatham, then by tunnel to Millburn, where a head of 300 feet will permit of a gravity supply calculated at 60,000,000 gallons. It is stated by Prof. Cook, that this line is long, expensive, and would divert some streams from their present courses.

4. This plan, it is thought, could be advantageously modified by taking the water at Morristown through the ridge to Loantaka Brook, and thence in the natural channels to Chatham, from which it could be taken, at an elevation of about 200 feet, through the mountain to near Millburn. Calculated supply, 100,000,000 gallons per diem.

The four preceding plans contemplate drawing the ultimate water supply from the same hydrographical basin, as that in which the communities to be supplied are located. This appears to be a natural arrangement, and one which would have a further advantage if, in the increasing population of portions of the state, now sparsely settled, disputes might in equity arise, concerning the right of one community to use water apparently designed by nature for the water supply of another community, located in a distincthy drographical basin.

Besides these four, there are two other plans of ultimate water supply, which propose the use, either wholly or in part, of the water supply of foreign hydrographical basins, viz.:

5. *L. B. Ward's Plan.*—The water of the Passaic is to be taken at or near Page's dam, above Chatham, and carried by tunnel through the mountain to Millburn. The supply of water could be increased by connecting the head waters of the Raritan, and, if needed, by opening the channel from the Rockaway at Berkshire Valley to the Black River, and from that across to Dead River and the

Passaic again. More than 100,000,000 gallons daily could be supplied in this way. The author of this plan has carefully elaborated the details, which are well worthy the study of those interested in the solution of this problem.

6. *The Morris Canal Plan.*—The waters are drawn from Lake Hopatcong, with a drainage area of 27 square miles, and altitude of 914 feet above mean tide, and Greenwood Lake, altitude 665 feet, and drainage area 32 square miles. It is stated in the report to the Newark Aqueduct Board, by the committee, of which John C. Campbell, C. E., was chairman, that the canal, as an open conduit, can deliver at the head of Bloomfield, at any season, a daily supply of thirty million gallons. It further states that the waters of the Rockaway, the Ramapo, the Ringwood, and the Pequanock, with a total of 463 square miles of drainage area (all of which is above the level of the canal, and in connection with it at Boonton and the head of the Pompton feeder), may be secured to increase the Morris Canal supply.

[To be continued.]

ON THE DEVELOPMENT OF THE CHEMICAL ARTS, DURING THE LAST TEN YEARS.[i]

By Dr. A. W. Hofmann.

From the *Chemical News*.

[Continued from Vol. lxxv, page 37.]

Nitrate of Potash.—For the manufacture of gunpowder, nitrate of soda is not adapted, on account of its hygroscopic nature. For this purpose it must be transformed into potash saltpetre. Hence large establishments have latterly sprung up for the manufacture of what is called, in contradistinction to the natural article, "converted saltpetre."

The industrial preparation of this converted nitre seems to have been undertaken almost simultaneously by Wöllner,[ii] Grüneberg,[iii]

[i] "Berichte über die Entwickelung der Chemischen Industrie während des letzten Jahrzehends."

[ii] Wöllner, *Polyt. Notizbl.*, 1860, 49; *Wagner Jahresber.*, 1860, 204. *H. Grüneberg, Wagner Jahresber.*, 1869, 208.

[iii] H. Grüneberg, *Polyt. Notizbl.*, 1863, 968; *Wagner Jahresber.*, 1868, 288.

and Nöllner[i] about 1855, when a considerable demand for saltpetre suddenly sprung up in consequence of the Crimean war. Up to that date India and the native nitre-beds had supplied all that was required by the powder works. The importation of Indian saltpetre has latterly declined, and the manufacture of native saltpetre has come entirely to an end in England, France, and Germany, and is only now carried on upon a small scale in Sweden, Russia, and Spain.

The method now almost exclusively adopted for the production of converted saltpetre depends on the double decomposition of nitrate of soda and chloride of potassium, so as to yield nitrate of potash and chloride of sodium. Since the discovery and working of the deposits of potassium salts at Stassfurt the chloride of potassium is not merely the cheapest source of potash, but admits of the most complete decomposition.

As early as 1858, Anthon[ii] published a practical process for the manufacture of potash saltpetre from Chilian nitre and potassium chloride. In 1859 Kuhlmann[iii] reconsidered this method of manufacture, with especial regard to French requirements, and Waltl[iv] proposed to use the mother-liquor of brine springs or of sea-water, containing chloride of potassium, in the preparation of saltpetre.

A full description of the method of manufacturing converted saltpetre, as used in England in 1866, has been published by Lunge.[v] Equivalent weights of Chili nitre and Stassfurt potassium chloride—whose composition has previously been determined by analysis—are dissolved in water in large iron pans, and heated to a boil by the direct introduction of steam. The lye, after settling, is allowed to cool whilst constantly stirred, when the potash saltpetre is deposited as a fine crystalline meal, which is placed in wooden troughs lined with lead, and washed with water till a sample, on being tested with chloride of silver, contains only $\frac{1}{100}$ per cent. chloride of sodium. When the washing is completed, the still adherent mother-liquor is removed by means of centrifugals, and the saltpetre is then dried upon wooden surfaces in heated rooms. The mother-liquors are concentrated over an open fire. when the bulk of the common salt is deposited and

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[i] Nöllner, *Polyt. Notizbl.*, 1867, 370.

[ii] Anthon, *Dingler*, cxlix. 39; *Chem. Centralblatt*, 1858, 560; *Wagner*, 1858, 154.

[iii] Kuhlmann, *Bull. Soc. d'Encouragement*, 1859, 567; *Wagner*, 1859, 182.

[iv] Waltl, *Polyt. Central.*, 1859, 129; *Wagner*, 1859, 182.

[v] Lunge, *Dingler*, clxxxii, 385; *Wagner*, 1866, 223.

"fished out," whilst the liquid, on cooling, yields a further quantity of pulverulent saltpetre. In another establishment a solution of potassium chloride is first prepared, of specific gravity 1·200 to 1·210; in this the equivalent weight of Chili saltpetre is dissolved, and the solution is then concentrated over an open fire. The common salt which continually separates out is withdrawn, drained, and washed with water as long as it retains ½ per cent. saltpetre, the washings being returned to the pan. When the lye is concentrated to specific gravity 1·500, it is allowed to settle for a short time, when the common salt, as deposited, carries with it all dirt, and the clear solution is run into the crystallizers. By means of occasional agitation, the crystals are obtained as fine as those of Epsom salt: the mother-liquor is drawn off, and the crystals allowed to drain perfectly. They are then covered with cold water; after seven or eight hours the liquid is again drawn off, and after the crystals have drained for twelve hours, more water is poured on. This washing process is repeated till the desired purity is reached, which is generally the case after the second washing.

The author saw, in 1862, in a Scotch manufactory, this method so modified, that the dry salts, chloride of potassium, and Chili saltpetre, in equivalent proportions, were mixed and heated with a quantity of mother-liquor insufficient for complete solution. The operation was carried on in a number of iron cylinders, not very large, fitted with mechanical agitators, and heated with steam-jackets. The abundant aqueous vapors evolved were conducted through a lateral flue into the chimney of the works. After agitation for several hours, during which time the loss due to evaporation is constantly made up by fresh supplies of mother-liquor, the transformation is complete, the liquid contains the whole of the nitrate of potash in solution, and the solid salt consists of fine crystals of chloride of sodium. From the solution, clarified by settling, pulverulent saltpetre is obtained by disturbed crystallization, and freed by washing from adherent chloride of sodium. The salt is also washed in a similar manner till free from saltpetre. The mother-liquors and washing-waters are used in the treatment of fresh quantities of Chili saltpetre and chloride of potassium, and with careful working are said to be completely used up.

(To be continued.)

Lavoisier Medal.—The Société d'Encouragement pour l'Industrie Nationale has awarded its grand Lavoisier medal, for the progress of the chemical arts, to Walter Weldon, for his method of recovering chlorine from waste liquors. The consequent saving has reduced the price of chlorine 30 per cent.—*Les Mondes.* C.

Improved Telephone.—M. Trouvé has experimented, with a view to render the Bell telephone more sensitive, in order that satisfactory communications may be sent to greater distances than are now practicable. He substitutes a cube, or a polyhedron, with a vibrating membrane on each of the sides, so as to multiply the number of induced currents, and thus give the electric waves greater intensity.—*Les Mondes.* C.

Florentine Water-Works.—Among the most important enterprises of modern Italian engineering, are the new water-works of Florence. The object of the undertaking is thus stated in *Giornale del Genio Civile:* "To collect in a gallery, excavated near the city, the subterranean waters which filter through the sand and gravel which form the subsoil of the great valley of the Arno; to convey them into ample basins, from which, by means of powerful pumps, they may be distributed in canals, using the waters of the Arno and Corliss steam engines for motive force, and to establish ample reservoirs, above the level of the city, to receive the excess or supply the deficiency of hourly consumption, the reservoirs acting like the governors of a steam engine." C.

Temperature and Efficiency of Nitro-Glycerine.—Although the temperature developed by the combustion of nitro-glycerine has not been accurately measured, there is reason to believe that it is more than twice as great as that of gunpowder. A volume of powder produces, at the ordinary temperature, 190 volumes of gas; in consequence of the heat liberated, this gas is expanded to four times its volume, yielding 760 volumes of gas immediately after the explosion. A volume of nitro-glycerine produces 1300 volumes of gas at the ordinary temperature; in consequence of the heat set free, the expansion is supposed to reach 13000 volumes. At the slate quarries in the north of Wales, nitro-glycerine has been employed for a considerable time, and a single explosion accomplishes as much as four or five explosions with powder. Equally favorable results have been obtained at Freyberg and in Belgium.—*Revue Industr.* C.

Strength of Cast Steel.—As a proof of A. von Gautier's statement, that the strength and ductility of steel are increased by heating and subsequent slow cooling, von Tunner experimented with No. 4 Inneberg manganese-steel. His experiments were satisfactory, but he obtained still better results by hammering, rolling, or pressing the reheated steel.—*Kärnthn. Zeitsch.* C.

Protection of Bank-Notes against Fire.—A German inventor has devised a bank-note album, with leaves of asbestos-paper, for the protection of notes, checks, and valuable documents. By placing them between the asbestos leaves, especially if the book is firmly clasped, they may be kept legible, even after exposure to a fire which reduces them to cinders.—*Papier-Zeitung.* C.

Globular Lightning.—M. G. Planté has experimented upon distilled water with an electric current of high tension, by joining 20 secondary batteries, of 40 couples each, producing a current about equivalent to 1200 Bunsen elements. He thus produces a number of beautiful luminous effects, constituting "a true electric kaleidoscope;" imitates the phenomena which result from the fall of liquid drops on a plain surface, and shows that, with a sufficient quantity and tension of electricity, we can obtain not only electrized liquid globules, but even the electric spark itself in globular form.—*Comptes Rendus.* C.

Chemical Changes in Works of Art.—S de Luca describes six bronze goats, with lead bases, found in Pompeii. They were evidently designed for weights. The lead has been mostly changed into an amorphous mass of white carbonate. On the one-pound weight a portion has became translucent and partially crystalline. On the ten-pound weight there are definite crystals of carbonate, with a brilliant lustre. Their formation, in a period accurately known, is noteworthy.—*Comptes Rendus.* C.

Tunnel under the English Channel.—The experimental works at Sangatte are well under way. The shaft is already sunk to a depth of 100 metres below low water mark. Two pumps are employed to remove the water, which flows abundantly. A trial gallery has been begun, in the chalk, under the sea, perpendicular to the shaft. It is to be 1 kilometre long, and, if no difficulties arise during its completion which show that the work is impracticable, the tunnel will be promptly begun.—*Les Mondes.* C.

Artificial Corundum and Silicate Crystals.—MM. E. Fremy and Feil have been very successful in producing alumina crystals, especially rubies and sapphires, in masses sufficient to be used for clocks, and cut by lapidaries. They have often operated on 20 or 30 kilogrammes of materials at a time, which were subjected to an intense temperature, without interruption, for twenty days. They begin by forming a fusible aluminate, and heating it to a bright red, with some silicious substance, when the aluminum slowly separates from its saline combination, in presence of the flux, and crystallizes. Their paper mentions four different causes of crystallization; their best results, however, have been obtained with aluminate of lead. They describe the method of preparation for white corundum crystals: for rubies, they add 2 to 3 per cent. of bichromate of potash; for sapphires, a small quantity of oxyd of cobalt, mixed with a trace of bichromate of potash. Their rubies scratch quartz and topaz; their density is 4 to 4·1; like natural rubies, they lose color under intense heat, and resume it upon cooling; lapidaries have often found them even harder than natural rubies; they rapidly wear out the best grinding wheels of tempered steel. By submitting to a red heat, for many hours, equal weights of silex and of aluminum-fluoride, they obtain a fluoride of silicium and a crystallized body resembling *dysthène*, or silicate of aluminum. Other artificial silicates are also described.—*Comptes Rendus.* C.

Underground Telegraphs.—On the 23d of July, 1877, the underground telegraph line was completed between Berlin and Mainz, by sinking a river-cable in the Rhine, between Mainz and Castel. This is the longest underground line in the world (about 600 kilometres). A special incentive to the costly undertaking was the desire to guard the main line of German telegraphs against the frequent accidents and interruptions to which air lines are exposed, and the expense for repairs which they often entail. As an illustration of such expense, Wohlfahrt states, in his description of the line (*Dingler's Pol. Jour.*, 226, 363), that in the storm which occurred during the night of March 12-13, 1876, on the government telegraph lines there were 1073 poles broken, 9372 poles displaced or overthrown, 1696 stays and anchor-posts torn out, while the wires were broken in 1631 places, and twisted in 729 places. Consequently two-fifths of all the lines, or 52,390 kilometres, were partially useless for many days. The merely provisory repairs of this single night's

damage cost 44,000 marks, and the indirect loss to trade and commerce was incalculable. In times of a political crisis, or at the outbreak of a war, such widespread interruption to customary intercourse might be attended with the most serious consequences. C.

Artificial Feldspars.—M. Hautefeuille produces tridymite, orthoclase and triclinic feldspars, by exposing a mixture of silex and alumina, in presence of acid tungstate of potash, to a temperature between 900° and 1000°. If the potassa and alumina have been properly proportioned, the tridymite and triclinic feldspars soon disappear, and their elements increase the crystals of orthoclase. After fifteen to twenty days' heating, these crystals remain alone, and they may be easily separated, since the tungstate is soluble in boiling water. If soda is substituted for potash, the crystals are of albite. The committee to which M. Hautefeuille's paper was submitted (MM. H. Sainte-Claire Deville, Des Cloizeaux, and Daubrée) recommend its publication in the *Recueil des Mémoires des Savants Etrangers.*

C.

Utilization of Waste Gases.—M. L. Cailletet has been studying the composition and the industrial employment of the gases which circulate in the hottest part of puddling furnaces. He finds a considerable proportion of carbonic oxide, and a large quantity of minutely divided carbon, so that, even after their passage under steam generators, the gases retain an important quantity of combustible materials, which can easily be rekindled and nearly all consumed, by the help of processes which he has described.—*Comptes Rendus.*

C.

Engraving on Glass by Electricity.—M. G. Planté, whose electric experiments on glass and crystal have been already noticed in the JOURNAL, covers a surface of glass or crystal with a concentrated solution of nitrate of potash, by simply pouring the liquid on the plate, placed horizontally on a table or in a shallow dish. In the liquid film and along the borders of the plate he lays a platinum wire communicating with the poles of a secondary battery of 50 to 60 cells, then holding in his hand the other electrode of platinum wire surrounded, except at the end, by an insulating sheath, he touches the glass covered by the thin film of saline solution, at the points which he wishes to engrave. A luminous notch is made wherever the electrode touches, and however rapidly one writes or draws, the

marks are found sharply engraved on the glass. In writing or drawing slowly, the marks are engraved deeply; if the wire, which serves as electrode, is sharpened to a point, the lines may be made extremely fine. Either electrode may be used as a graver, but a weaker current suffices for the negative electrode. Although these results have been obtained by using secondary batteries, it is evident that any other source of electricity of sufficient quantity and tension, might be employed for continuous work, such as a Bunsen pile of a sufficient number of elements, or a gramme machine, or even a magneto-electric machine with reciprocating currents.—*Comptes Rendus.* C.

Caucasus Railway.—Herr von Statkowski, Russian Imperial State Councillor and Chief Inspector of the Swiss Poti-Tiflis Railway, has prepared plans for a road over the Caucasus, by the Maga Pass. The principal tunnel will be 6541·6 metres long; the next in length, 1167 metres; the aggregate length of 84 other tunnels, 12,960 metres.—*Zeits. des Oester. Ing.- und Arch.-Vereins.* C.

Early Paper.—M. Charles Schmidt publishes an account, in the *Bulletin de la Société Industrielle de Mulhouse*, of the water-marks upon paper used in Strasbourg, from 1343 to 1525. The earliest paper was made of cotton. The Arabs introduced it into Spain and Italy, whence it spread into other European countries. It was too soft to be durable. Paper made of old linen rags is first mentioned in 1120, by Peter, the Venerable Abbé of Cluny, who speaks of it as among the well-known materials for book-making. The machinery which was employed in Alsace in the fourteenth century, consisted of a mill-wheel for driving the piles, which reduced the rags to pulp, a vat, some moulds made of a tissue of wire, surrounded by a wooden frame, squares of felt for drying the sheets, and a sizing apparatus. Before A. D. 1400, at least twenty different factories were in operation. C.

Dry Graphite for Steam Cylinders.—Mr. W. J. Williams, engineer, 611 St. John St., Phila., has called my attention to the successful use of dry pulverized graphite for lubricating steam cylinders. He applies 137 grains twice a day, introducing it into the cylinder through the usual form of tallow-cup. Six months of continuous use, in an $11'' \times 30''$ horizontal engine, working to its full capacity, prove this lubricant superior in every way to oils or tallow, both of which he had used for years. No oil whatever is introduced with

the graphite. Besides satisfying all the lubricating needs of the cylinder, the joints, where gum is used, last longer, and show less of leakage. At 30 cents per pound, this engine would require $1\frac{1}{6}$ cents' worth per day. J. H. C.

Improved Method of Managing Steam-Boiler Fires.—When the furnace-door of a steam boiler is opened, there should be a simultaneous partial closing of the damper to prevent sudden chilling of the boiler and flues. To accomplish this, with certainty, for every opening of the doors, Mr. Wm. Weightman, of Powers & Weightman, has had arranged and applied a system of levers and rods, connecting the furnace-door with the damper, so contrived that whether there be one or more doors to one furnace, or to which one damper is supplied, the act of opening any one door will invariably close the damper. Whether this application of simple and ingenious devices is new, or not, every engineer will regard it as one of the good things for aiding the better management of steam-boilers.

J. H. C.

New Leveling Device.—Every millwright experiences difficulty in leveling shafting, when pulleys, hangers, walls, etc., are in the way of applying the "straight edge" from bearing to bearing which it is desired to bring to a level. Mr. Geo. Jennison, millwright at Powers and Weightman's, has adapted a very simple and readily applied apparatus, which can be used without the usual "level boards" and "straight edges," and without regard to the obstructions in the way.

He takes an ordinary $\frac{3}{8}''$ or $\frac{1}{2}''$ gum tube, say 16 or 20 feet long, and to each end secures a stout glass tube 10″ to 12″ long; fills the gum tube with water to within, say, 4″ of each end of the glass tubes, puts a cork in each, and the apparatus is complete. To use this, hold each glass vertically at the bearings, and withdraw the corks; the water will soon find its level, and show how the bearings stand with regard to the level line. J. H. C.

The Liquefaction of Gases, and the Artificial Production of Low Temperatures.—In the JOURNAL OF THE FRANKLIN INSTITUTE for January, 1874 (p. 9), will be found a brief notice, by Prof. E. J. Houston, of a German refrigerating machine, proposed for making ice. Prof. Houston, after commenting upon the method of employment of the cold of expansion as the agent for the removal

of heat from compressed air, suggests modifications of construction of the apparatus, "which would render its cold producing power almost unlimited," and he says, in conclusion of his notice, that the great scientific advantages to be expected to accrue from the modified apparatus, are the following:

1st. The confirmation or otherwise of the "absolute zero," as determined by the expansion or contraction of gases by heat or cold.

2d. The liquefaction and subsequent solidification of many of the incoercible gases, the determination of their physical peculiarities as liquids or solids, together with their crystalline form.

3d. The action of intense cold on the chemical affinities of certain gaseous compounds.

4th. The action of intense cold on the color of certain chemical compounds.

The methods proposed by Prof. Houston were those followed by the two eminent chemists, Pictet and Cailletet, in their recent accomplishments in liquefaction of gases. The complete determination of the four problems must follow these results in time. The eventual liquefaction, and perhaps solidification, of all gases, has been anticipated as a probability by most chemists and physicists.

Prof. Houston's article of four years since, anticipated the way in which it has been done. B.

The Reaction Principle in Dynamo-Electric Machines.—Quite an extended controversy has recently been carried on through the columns of *Engineering*, between Dr. C. W. Siemens and Mr. S. A. Varley, in regard to the relative claims of the latter, and of Dr. Werner Siemens, to priority in the discovery and application of the reaction principle in dynamo-electric machines.

The following extract from a letter of Mr. Robert Sabine, published in the same journal, appears to give a fair statement of their respective claims, and also those of Professor Wheatstone, and serves as another illustration of how frequently it occurs that several persons are at the same time pursuing independently the same investigation, and arrive at the same results, at dates, the intervals between which are too small to entitle any one of them to all the credit. In this case the honors seem about evenly divided.

* * * "In the little controversy which has been going on, the claims of the late Professor Wheatstone have been, to a great extent,

inadvertently passed over. I therefore hasten to supply the omission as far as I am able.

"At what date 'the idea of making a machine which would work into itself occurred to' Professor Wheatstone, it is, of course, after his death, impossible to determine, unless some manuscript notes should turn up in evidence. I am also unable to ascertain when his *first* experimental apparatus was made and tried. We must therefore start from the later stage, viz., the finished machines which were exhibited at the Royal Society in February, 1867.

"These machines were made for Professor Wheatstone by Mr. Stroh in the months of July and August, 1866. When they were finished, tried, and approved of, they were, in the usual course of business, charged for by Mr. Stroh on the 12th of September, 1866.

"Mr. S. A. Varley says his 'machine (as it was exhibited in the Loan Collection) was completed and tried at the end of September, or the beginning of October, 1866.'

"Dr. Siemens says that his brother 'tried his first experimental machine in December, 1866.'

"It is clear, therefore, that Professor Wheatstone's machines—those exhibited at the Royal Society—were completed, tried, and charged for before the first experimental machines of either Dr. Siemens or Mr. Varley were finished and ready for trial.

"The date when an undefined idea of making any machine first occurs to an inventor is of very little comparative importance, unless the idea be productive of some evidence of its being, without which one would naturally be inclined to suspect that memory might after the lapse of years be a little treacherous. Who had the first happy inspiration of a reaction machine, we can scarcely expect to know now. Of its fruits we have better evidence, and I venture to think that the claims of the three inventors in question stand thus:

"Professor Wheatstone was the first to complete and try the reaction machine.

"Mr. S. A. Varley was the first to put the machine officially on record, in a provisional specification dated the 24th of December, 1866, which was, therefore, not published until July, 1867.

"Dr. Werner Siemens was the first to call public attention to the machine, in a paper read before the Berlin Academy, on the 17th of January, 1867."

New Safety Heating Apparatus for Cars.—Among the most fruitful causes of loss of life in railroad accidents, is the burning of cars, which take fire from the stoves or other heating apparatus contained in them. In order to reduce the risk as far as possible, Messrs. Wood, Scull & Snyder, of this city, have devised a plan for heating the cars with steam generated in a boiler provided especially for that purpose, and placed in the baggage or smoking car.

The distribution of the steam-pipes in the cars, for heating, is well arranged, and contains some points of novelty. The essential feature of the apparatus, however, lies in the flexible joints in the pipes connecting the cars. These are so constructed as to yield freely to all the movements of the cars and yet remain tight, and are entirely self-acting in coupling and uncoupling.

This arrangement has been in constant use on the Camden and Atlantic Railroad for more than three months, giving great satisfaction. It is clear, that there being but one fire in the whole train (outside of the locomotive), and that at a considerable distance from the passengers, the risk of life from fire, in case of a "smash-up," is greatly reduced. It is also claimed that this arrangement is more economical in fuel, labor and maintenance than the best device for heating each car separately.

Drawings of the flexible self-coupling device, which renders this system practical, are promised us soon for publication. *

Engineers' Club of Philadelphia.—A society has recently been formed by the younger engineers of Philadelphia, having for its object the professional improvement of its members, encouragement of social intercourse among men of practical science, and the advancement of the various branches of engineering. Meetings for the discussion of scientific subjects and the reading of professional papers are held for the present at the residences of the members, on the first and third Saturdays in each month. The society is called the Engineers' Club of Philadelphia, and was formally organized on Monday, December 17th, 1877, when the following officers were elected:—President, Prof. L. M. Haupt; Vice-President, Coleman Sellers, Jr.; Secretary and Treasurer, Charles E. Billin.

Book Notices.

ELEMENTS OF THE METHOD OF LEAST SQUARES.—By Mansfield Merriman, Ph. D., Instructor in Civil Engineering in the Sheffield Scientific School of Yale College. London: MacMillan and Co., 1877. 12mo., pp. 200. For sale by J. B. Lippincott & Co.

Our readers have already become acquainted with Dr. Merriman's name, in connection with the subject of least squares, through his articles in the September, October and November numbers of the JOURNAL, for 1877. In the preface to his "Elements," he says:

"In writing the following pages I have had two objects in view: first, to present the fundamental principles and processes of the Method of Least Squares in so plain a manner, and to illustrate their application by such simple and practical examples, as to render it accessible to civil engineers who have not had the benefit of extended mathematical training; and secondly, to give an elementary exposition of the theory which would be adapted to the wants of a large and constantly increasing class of students."

These objects are both accomplished, so satisfactorily, that those who have had no experience in the practical use of this method, can soon make themselves familiar with some of its most useful applications. They will thus gain a ready means of simply formulating their results, so as greatly to enhance their value.

Even expert mathematicians, who have never made themselves thoroughly acquainted with the theory, but have only occasional calls for its use, will find the manual a convenient one for handy reference, to refresh their memory upon points which may be easily forgotten when out of practice. C.

THE MECHANICS OF ENGINEERING AND THE CONSTRUCTION OF MACHINES. By Dr. Phil. Julius Weisbach. Vol. II, Application of Mechanics to Machines. Translated from the fourth augmented and improved German edition, by A. Jay DuBois, Ph. D. 8vo, pp. 668. New York, John Wiley & Sons, 1877.

The long anticipated American translation of the second volume of Dr. Julius Weisbach's celebrated "Manual of the Mechanics of Engineering and the Construction of Machines," has at length appeared from the press of John Wiley & Sons, New York, and is about uniform in shape and appearance with Vol. I, published some years ago by Van Nostrand. Van Nostrand's Vol. I, a book of over

1100 pages, comprises the whole of Weisbach's first volume, as it appears in the fourth and latest German edition, and was translated by Mr. Eckley B. Coxe, who intended to complete the entire work in two additional volumes. Professional business, however, seems to have prevented the consummation of Mr. Coxe's design, as he finally relinquished the task to Prof. A. Jay DuBois, of the Sheffield Scientific School of Yale College, to whom we are, therefore, indebted for the translation now offered us. Dr. Weisbach's Vol. II (fourth German edition) is divided into two sections, the first treating of the application of the mechanical principles set forth in Vol. I, to structures of stability—such as roofs, bridges, retaining walls, etc. Prof. DuBois, deeming the subject already over-written, entirely omits this portion of the work, and begins his translation at the second section, which treats of the application of the mechanical principles to machines. This section is subdivided into two parts, discussing, first, the various motive powers and their reciprocal machines, hydraulics and air motors, etc.; and secondly, heat, the steam engine, etc.

Part first of Weisbach's second volume forms the subject matter of Prof. DuBois' work (Vol. II of the American translation), and he promises soon to give us a second volume (Vol. III. of the series), which will complete Weisbach's second volume, by giving us the remainder of his Section II. In order to add to the completeness of his book, Prof. DuBois has prefaced it with an introduction of 53 pp., briefly rehearsing those principles set forth in Vol. I which are most frequently referred to in Vol. II. He discusses here, in a more or less general way, such topics as work, effective delivery, unit of work, inertia, momentum, velocity, acceleration of gravity, *vis viva*, impart, centrifugal force, etc., and gives the formulæ most often required in the pages to follow.

This introduction, although in part made up of selections from Vol. I, is very largely composed of new matter from the pen of Prof. DuBois, who arrives at Weisbach's results by new methods, and gives his own definitions and descriptions in exceptionally clear and concise terms. Prof. DuBois, in his introduction, has not confined himself exclusively to Weisbach's investigations, but has availed himself of the results obtained by the labors of more recent investigators; and his addition makes the book complete and self-contained, and enables it to be used satisfactorily without a constant reference to the previous volume, and, indeed, will possibly permit it to be employed as a college text-book, even to the exclusion of Vol. I.

Prof. DuBois, in thus rendering accessible to the English-speaking public so valuable a book, has made a very important addition to our technological library; and it is most sincerely to be hoped that he may be enabled to prosecute his labors until the whole of Dr. Weisbach's great work is reduced to English language and nomenclatures.

S.

Franklin Institute.

HALL OF THE INSTITUTE, Feb. 20th, 1878.

The stated meeting was called to order at 8 o'clock P. M., the President, Dr. R. E. Rogers, in the chair.

There were present 132 members and 26 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting 12 persons were elected members of the Institute, and the following donations were made to the Library:

Reports of the Hartford Steam Boiler Inspection and Insurance Company. 1873 to 1876 inclusive. From the Company.

Monthly reports on the Commerce and Navigation of the United States. By Edward Young. For fiscal years ending June 30th, 1874-5.

Quarterly reports of the Chief of the Bureau of Statistics, for 1875-6 and 1876-7.

Annual report of the Chief, for fiscal year ending June 30th, 1876.

First annual report on the Internal Commerce of the United States. By Jos. Nimmo, Jr. Or Part 2d of report of Chief of Bureau of Statistics, etc.

Rapport special sur l'imigration, etc. Par E. Young, 1872.

List of Merchant Vessels and Vessels of the U. S. Navy and Revenue Marine service, 1876. From the Chief of Bureau.

Reports of the Chief of Ordnance to the Secretary of War, for 1872-3, and 1875 to 1877, inclusive.

Ordnance Memoranda, No. 14, 17 to 20, Washington, 1873-77. From Chief of Bureau.

Pennsylvania Archives, Second Ser., Vol. 5th, Harrisburg, 1877. From Historical Society, Penna.

Phœnix Iron Company, Album of Iron Manufactured. From the Company.

Meteorological Observations, made at the U. S. Naval Observatory, during the year 1875. From Naval Observatory.

An address on the Endowment of Research. By E. C. Pickering. Salem, 1875. From the Author.

Circulars of information of the Bureau of Education, Nos. 1 and 2, 1877.

Contributions to the History of Medical Education and Medical Institutions, in the U. S. of America, 1776 1876. Special report of N. S. Davis. Washington, 1877. From the Bureau of Education.

Whittaker's Compound Pitch, True Screw Propeller. Letters Patent, 1877. From W. P. Street.

Des Paratonnerres à pointes, à conducteurs, etc. Par M. Meslens. From the Author.

American Engines and Fairlie Engines compared. By W. W. Evans. From the Author.

Reply to criticisms made by Dr. Hagen, of Germany, on the Physics and Hydraulics of the Mississippi. By Humphries and Abbot. From Chief of Engineers.

The Pennsylvania Railroad; its origin, construction, condition, etc. By W. B. Sipes. Phila., 1875. From P. L. Farmer, Gen. Pass. Agent.

Message of the President of the United States, containing reports of Secretary of the Navy and Postmaster-General, for 1866.

Essay on the use of various Alloys for founding Cannon. By Levy and Runkle, Brussels, 1870. Translation. Washington, 1872.

Annual report of the Secretary of the Navy, on the Operations of the Dept., for the year 1871. From the Secretary of the Navy.

Annual report of the Secretary of the Treasury, on the state of the Finances, for the year 1877. From the Secretary of the Treasury.

Annual report of the Chief of Engineers for the year 1877, in two parts. From the Chief of Engineers.

Rules of practice in the United States Patent Office, Aug., 1877. From the Commissioner of Patents.

Annual report of the Director of Harvard College Observatory. Cambridge, 1877. From E. C. Pickering.

25th annual report to the Council of City of Manchester, on the working of the Public Free Libraries, 1876-7. Manchester, 1877. From the Council.

An inquiry into the state of the Ancient Measures. By B. P. Hooper. From W. P. Tatham.

The Actuary also reported that at the last meeting of the Board of Managers, Prof. Robert H. Thurston, of Hoboken, N. J., was unanimously nominated for election as a corresponding member of the Institute.

Mr. Henry P. M. Birkinbine then read the paper announced for the evening, being on "The Future Water Supply of Philadelphia."

The Secretary presented his report, embracing illustrated descriptions of the method employed by Mr. James P. Davis for moving a large brick house; Edgerton's new apparatus for carburetting air for illumination; Grace Spark Arrester; Sommers' Differential Valve; and a specimen of the brass tubes of the surface condenser of one of the Pacific Steamers, which were badly corroded at the point where they were fastened in the tube sheets with wooden ferrules.

Mr. Hector Orr made some remarks on the loss of two highly esteemed and useful citizens, both of whom have long been members of the Institute, and presented the following resolutions, which were unanimously adopted:

Resolved, That by the death of JOHN WIEGAND, ESQ., we lose an early member and efficient friend of this Institute, an accomplished mechanic, and highly useful citizen, who has discharged the various duties, public and private, of a long life, with honor to himself and benefit to his fellow men. We here emphatically acknowledge our loss, and commend his example to all survivors.

Resolved, That the Franklin Institute hereby records its testimony to the loss sustained by it and this community, and the nation at large, in the death of our late member, WILLIAM WELSH, ESQ., who, after a long term of absence, had recently returned to a most gratifying activity in our midst, who leaves unfinished much work which seemed adapted to his hand, and makes a vacancy in our ranks that we cannot hope soon to fill. Joining in the universal eulogium of the public, we bid him farewell, and repeat to each other the words of Edmund Burke: "Revere—imitate—persevere!"

An amendment to the by-laws, proposed by Mr. W. P. Tatham, by the substitution of the following for the existing Art. XVI, was read, and laid over to the next stated meeting:

Amendments to these by-laws to be proposed at any stated monthly meeting, shall be posted upon the notice board by the first of the month. Such proposition, when presented to the meeting, may be considered, amended, referred, postponed or rejected, or ordered to be published weekly in two or more daily papers published in the City of Philadelphia, by a majority vote.

At a subsequent stated meeting, after such publication, the amendment may be adopted by a vote of two-thirds of the members present, except in the case of Art. I, relating to capital stock, which cannot be altered unless by a vote of a majority of the stock represented.

On motion of Mr. H. Cartwright, Prof. Robt. H. Thurston was unanimously elected a corresponding member of the Institute.